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(54) Title: NEW COCHLEATE FORMULATIONS, PROCESS OF PREPARATION AND THEIR USE FOR THE DELIVERY OF BIOLOGICALLY RELEVANT MOLECULES

(57) Abstract: A process for producing a small-sized, lipid-based cochleate. Cochleates are derived from liposomes which are suspended in an aqueous two-phase polymer solution, enabling the differential partitioning of polar molecule based-structures by phase separation. The liposome-containing two-phase polymer solution, treated with positively charged molecules such as Ca<sup>2+</sup> or Zn<sup>2+</sup>, forms a cochleate precipitate of a particle size less than one micron. The process may be used to produce cochleates containing biologically relevant molecules.

**NEW COCHLEATE FORMULATIONS,  
PROCESS OF PREPARATION AND THEIR USE FOR THE  
DELIVERY OF BIOLOGICALLY RELEVANT MOLECULES**

**CROSS-REFERENCE TO RELATED APPLICATION**

This is a Continuation-in-Part of U.S. Application No. 09/235,400 filed January 22, 2000.

**FIELD OF THE INVENTION**

5        The present invention relates to a novel method for preparing a novel lipid-based cochleate delivery system, the preparations derived from the lipid-based cochleate delivery system, such as drugs, carbohydrates, vitamins, minerals, polynucleotides, polypeptides, lipids and the like, and the use of these preparations.

10        **BACKGROUND OF THE INVENTION**

The ability of biologically relevant molecules to be administered via the oral route depends on several factors. The biologically relevant molecule must be soluble in the gastrointestinal fluids in order for the biologically relevant molecule to be transported across biological membranes for an active 15 transport mechanism, or have suitable small particle size that can be absorbed through the Peyer's Patches in the small intestine and through the lymphatic system. Particle size is an important parameter when oral delivery is to be achieved (*see* Couvreur et al, *Adv. Drug Delivery Rev.*, 10:141-162 (1993)).

20        The primary issue in the ability to deliver drugs orally is the protection of the drug from proteolytic enzymes. An ideal approach is to incorporate the drug in a hydrophobic material so that the aqueous fluids cannot penetrate the system. Lipid-based cochleates are an ideal system that can achieve this purpose.

25        The advantages of cochleates are numerous. The cochleates have a nonaqueous structure and therefore they:

- a) are more stable because of less oxidation of lipids;
- b) can be stored lyophilized, which provides the potential to be stored for long periods of time at room temperatures, making them

advantageous for worldwide shipping and storage prior to administration;

- c) maintain their structure even after lyophilization, whereas liposome structures are destroyed by lyophilization;
- 5 d) exhibit efficient incorporation of biologically relevant molecules into the lipid bilayer of the cochleate structure;
- e) have the potential for slow release of a biologically relevant molecule *in vivo* as cochleates dissociate;
- 10 f) have a lipid bilayer which serves as a carrier and is composed of simple lipids which are found in animal and plant cell membranes, so that the lipids are non-toxic;
- g) are produced easily and safely;
- 15 h) can be produced as defined formulations composed of predetermined amounts and ratios of drugs or antigens.

15 Cochleate structures have been prepared first by D. Papahadjopoulos as an intermediate in the preparation of large unilamellar vesicles (see U.S. Patent No. 4,078,052). The use of cochleates to deliver protein or peptide molecules for vaccines has been disclosed in U.S. Patent Nos. 5,840,707 and 5,643,574. The use of cochleates to orally deliver drugs, nutrients, and flavors 20 have been described in U.S. Patent No. 5,994,318.

25 However, the advantages of using small-sized cochleates have only recently been explored. The effective oral delivery of drugs that are mediated by hydrogel-isolated cochleates has been described in U.S. Application Serial No. 09/235,400. However, the effective delivery of hydrogel-isolated cochleates have not been described for other biologically relevant molecules such as drugs, polypeptides, polynucleotides, antigens, vitamins, minerals, amino acids, saccharides, flavor oils, and the like.

#### SUMMARY OF THE INVENTION

Accordingly, it is an object of this invention to provide a method for 30 obtaining a hydrogel-isolated cochleate of a particle size of less than one micron. The method further comprises the steps required to encochleate at

least one biologically relevant molecule in the hydrogel-isolated cochleates in an effective amount.

A "biologically relevant molecule" is one that has a role in the life processes of a living organism. The molecule may be organic or inorganic, a 5 monomer or a polymer, endogenous to a host organism or not, naturally occurring or synthesized in vitro, and the like. Thus, examples include vitamins, minerals, flavors, amino acids, toxins, microbicides, microbistats, co-factors, enzymes, polypeptides, polypeptide aggregates, polynucleotides, lipids, carbohydrates, nucleotides, starches, pigments, fatty acids, hormones, 10 cytokines, viruses, organelles, steroids and other multi-ring structures, saccharides, metals, metabolic poisons, drugs, and the like.

These and other objects have been obtained by providing an encochleated biologically relevant molecule, wherein the biologically relevant molecule-cochleate comprises the following components:

15        a) a biologically relevant molecule,  
              b) a negatively charged lipid, and  
              c) a cation component,

wherein the particle size of the cochleate is less than one micron.

#### BRIEF DESCRIPTION OF THE FIGURES

20        Figure 1 is a schematic of the process by which the hydrogel-isolated cochleates of the present invention, with or without a biologically relevant molecule, are obtained.

25        Figures 2A and 2B illustrate a particle size distribution (weight analysis) of hydrogel-isolated cochleates either loaded with amphotericin B (AmB) (Fig. 2A) or empty (Fig. 2B) as measured by laser light scattering.

Figures 3A and 3B illustrate microscopic images of a mixture of liposomes in dextran dispersed into PEG gel solution. The small black dots are dextran particles formed by dispersing the dextran phase in the PEG phase. The large open circles are formed by the fusion of small dextran particles. 30 Partition of liposomes favors the dextran phase as indicated by a yellow color of AmB. Fig. 3B: Microscopic images of the sample shown in Fig. 3A after

treatment with  $\text{CaCl}_2$  solution. The black objects in circles, are cochleates formed by the addition of  $\text{Ca}^{2+}$  ions.

Figures 4A-4F illustrate microscopic images of the sample shown in Figs. 3A and 3B after washing with a buffer containing 1 mM  $\text{CaCl}_2$  and 5 100 mM NaCl. Aggregates are formed by the cochleate particles (Fig. 4B). A suspension shown in Fig. 4A following the addition of EDTA. Cochleate particles opened to liposomes with a diameter of 1-2 microns, indicating the intrinsic size of the cochleate particles is in the sub-micron range (Fig. 4C). AmB hydrogel-isolated cochleates precipitated with zinc according to the 10 procedure described in Example 14 (Fig. 4D). Cochleates displayed in Fig. 4C after treatment with EDTA (Fig. 4E). Empty hydrogel-isolated cochleates precipitated with zinc according to the procedure described in Example 13 (Fig. 4F). Cochleates displayed in Fig. 4F are after treatment with EDTA.

Figure 5 illustrates micrographs of hydrogel-isolated cochleates after 15 freeze fracture.

Figure 6 illustrates growth inhibition of *Candida albicans* by hydrogel-isolated cochleates loaded with AmB at 0.625  $\mu\text{g}$  AmB/ml. Comparison is made to AmB in DMSO and AmBisome<sup>R</sup>.

Figure 7 illustrates the effect of hydrogel-isolated cochleates on the 20 viability of *Candida albicans* after 30 hours.

Figures 8A and 8B illustrate the efficacy of Amphotericin B-cochleates on macrophage cultures.

Figure 9 illustrates Amphotericin B tissue levels after administration of Amphotericin B-cochleates.

25 Figure 10 illustrates the time profile tissue concentration of AmB after a single dose administration of hydrogel-isolated cochleates loaded with AmB.

Figure 11 illustrates AmB tissue level 24 hrs after single dose and 24 hrs after a multiple dose regime.

30 Figure 12 illustrates correlation between Amphotericin B tissue level and the level of *Candida albicans* after administration of Amphotericin B cochleates.

**DETAILED DESCRIPTION OF THE INVENTION**

The present invention provides a solution to achieve effective oral delivery of drugs and other biologically relevant molecules by producing small-sized cochleates of less than one micron using new methods. The new 5 approach is based on the incompatibility between two polymer solutions, both of which are aqueous. Aqueous two-phase systems of polymers are well used for protein purification due to a number of advantages such as freedom from the need for organic solvents, mild surface tension and the biocompatibility of aqueous polymers (see P.A. Albertsson, "Partition of cell particles and 10 macromolecules", 3<sup>rd</sup> edition, Wiley NY (1986); and "Separation using aqueous Phase System" D. Fisher Eds, Plenum NY (1989)). It is known, for example, that large polar molecules such as proteins partition to a much higher concentration in a polymer phase with the physical characteristics similar to those of dextran than in a polymer phase with the physical characteristics 15 similar to those of PEG (see Forciniti et al, *Biotechnol. Bioeng.*, 38:986 (1991)).

According to the present invention there are provided methods for preparing small-sized, lipid-based cochleate particles and preparations derived therefrom, comprising a biologically relevant molecule incorporated into the 20 particles. The cochleate particles are formed of an alternating sequence of lipid bilayers/cation. The biologically relevant molecule is incorporated either in the lipid bilayers or in the interspace between the lipid bilayers. One of the methods for preparing the small-sized cochleates comprises: 1) preparing a suspension of small unilamellar liposomes or biologically relevant 25 molecule-loaded liposomes, 2) mixing the liposome suspension with polymer A, 3) adding, preferably by injection, the liposome/Polymer A suspension into another polymer B in which polymer A is nonmiscible, leading to an aqueous two-phase system of polymers, 4) adding a solution of cation salt to the two-phase system of step 3, such that the cation diffuses into 30 polymer B and then into the particles comprised of liposome/polymer A allowing the formation of small-sized cochleates, 5) washing the polymers out and resuspending the empty, drug or other biologically relevant

molecule-loaded cochleates into a physiological buffer or any appropriate pharmaceutical vehicle.

A second method for preparing the small-sized cochleates comprises detergent and a biologically relevant molecule and cation. The detergent is 5 added to disrupt the liposomes. The method comprises the following steps:

- 1) providing an aqueous suspension containing a detergent-lipid mixture;
- 2) mixing the detergent-lipid suspension with polymer A;
- 3) adding the detergent-lipid/polymer A suspension into a solution 10 comprising polymer B, wherein polymer A and polymer B are immiscible, thereby creating a two-phase polymer system;
- 4) adding a solution of a cationic moiety to the two-phase polymer system; and
- 5) washing the two-phase polymer system to remove the polymer.

15 A lyophilization procedure can be applied and the lyophilized biologically relevant molecule-cochleate complex can be filled into soft or hard gelatin capsules, tablets or other dosage form, for systemic, dermal or mucosal delivery.

Both methods described above lead to a small-sized particle with a 20 narrow size range that allows efficient oral delivery of biologically relevant molecules. The biologically relevant molecule partitions into either or both lipid bilayers and interspace, and the biologically relevant molecule is released from the cochleate particles by dissociation of the particles *in vivo*. Alternative routes of administration may be systemic, such as intramuscular, 25 subcutaneous or intravenous, or mucosal such as intranasal, intraocular, intravaginal, intraanal, or intrapulmonary. Appropriate dosages are determinable by, for example, dose-response experiments in laboratory animals or in clinical trials and taking into account body weight of the patient, absorption rate, half-life, disease severity and the like. The number of doses, 30 daily dosage and course of treatment may vary from individual to individual. Other delivery routes can be dermal, transdermal or intradermal.

The first step of either method of the present invention, which is the preparation of small liposomes, can be achieved by standard methods such as sonication or microfluidization or other related methods (see, for example, Liposome Technology, Liposome Preparation and Related Techniques, Edited 5 by Gregory Gregoriadis, Vol I, 2<sup>nd</sup> Edition, CRC Press (1993)).

The second step of either method comprises the addition, preferably by injection, of polymer A/liposome suspension into polymer B can be achieved mechanically by using a syringe pump at an appropriate controlled rate, for example a rate of 0.1 ml/min to 50 ml/min, and preferably at a rate of 1 to 10 10 ml/min.

The formation of hydrogel-isolated cochleates (with or without a biologically relevant molecule) is achieved in the third step by adding a positively charged molecule to the aqueous two-phase polymer solution containing liposomes. The positively charged molecule can be a polyvalent 15 cation and more specifically, any divalent cation that can induce the formation of a cochleate. In a preferred embodiment, the divalent cations include Ca<sup>++</sup>, Zn<sup>++</sup>, Ba<sup>++</sup> and Mg<sup>++</sup> or other elements capable of forming divalent ions or other structures having multiple positive charges capable of chelating and bridging negatively charged lipids, such as polycationic lipids. Addition of 20 positively charged molecules to liposome-containing solutions is also used to precipitate cochleates from the aqueous solution.

To isolate the cochleate structures and to remove the polymer solution, cochleate precipitates are repeatedly washed in a fourth step with a buffer containing a positively charged molecule, and more preferably, a divalent cation. Addition of a positively charged molecule to the wash buffer ensures 25 that the cochleate structures are maintained throughout the wash step, and that they remain as precipitates.

Finally, the medium in which the cochleates are suspended can contain salt such as calcium chloride, zinc chloride, cobalt chloride, sodium chloride, 30 sodium sulfate, potassium sulfate, ammonium sulfate, magnesium sulfate and sodium carbonate. The medium can contain polymers, such as pluronic, and polyethylene glycols. The biologically relevant molecule-cochleate is made

by diluting into an appropriate biologically acceptable carrier (e.g., a divalent cation-containing buffer).

The lipids of the present invention are non-toxic lipids and include, but are not limited to simple lipids which are found in animal and plant cell membranes. Preferably the lipid is a negatively charged lipid, more preferably a negatively charged phospholipid, and even more preferably a lipid from the group of phosphatidylserine, phosphatidylinositol, phosphatidic acid, and phosphatidyl glycerol. The lipids may also include minor amounts of zwitterionic lipids, cationic lipids, polycationic lipids or neutral lipids capable of forming hydrogen bonds to a biologically relevant molecule such as PEGylated lipid.

The polymers A and B of the present invention can be of any biocompatible polymer classes that can produce an aqueous two-phase system. For example, polymer A can be, but is not limited to, dextran 200,000-500,000, Polyethylene glycol (PEG) 3,400-8,000; polymer B can be, but is not limited to, polyvinylpyrrolidone (PVP), polyvinylalcohol (PVA), Ficoll 30,000-50,000, polyvinyl methyl ether (PVMB) 60,000-160,000, PEG 3,400-8,000. The concentration of polymer A can range from between 2-20% w/w as the final concentration depending on the nature of the polymer. The same concentration range can be applied for polymer B. Examples of suitable two-phase systems are Dextran/PEG, 5-20% w/w Dextran 200,000-500,000 in 4-10% w/w PEG 3,400-8,000; Dextran/PVP 10-20% w/w Dextran 200,000-500,000 in 10-20% w/w PVP 10,000-20,000; Dextran/PVA 3-15% w/w Dextran 200,000-500,000 in 3-15% w/w PVA 10,000-60,000; Dextran/Ficoll 10-20% w/w Dextran 200,000-500,000 in 10-20% w/w Ficoll 30,000-50,000; PEG/PVME 2-10% w/w PEG 3,500-35,000 in 6-15% w/w PVME 60,000-160,000.

The biologically relevant molecule is a molecule that has a role in the life processes of a living organism. The molecule may be organic or inorganic, a monomer or a polymer, charged, either positively or negatively, hydrophilic, amphiphilic or hydrophobic in aqueous media, endogenous to a host organism or not, naturally occurring or synthesized *in vitro* and the like.

The biologically relevant molecule may be a drug, and the drug may be an antiviral, an anesthetic, an anti-infectious, an antifungal, an anticancer, an immunosuppressant, a steroidal anti-inflammatory, a non-steroidal anti-inflammatory, a tranquilizer or a vasodilatory agent. Examples include

5 Amphotericin B, acyclovir, adriamycin, carbamazepine, melphalan, nifedipine, indomethacin, naproxen, estrogens, testosterone, steroids, phenytoin, ergotamines, cannabinoids, rapamycin, propanidid, propofol, alphadione, echinomycine, miconazole nitrate, teniposide, taxol, taxotere, nystatin, rifampin, and vitamin A acid.

10 The biologically relevant molecule may be a polypeptide such as cyclosporin, angiotensin I, II and III, enkephalins and their analogs, ACTH, anti-inflammatory peptides I, II, III, bradykinin, calcitonin, beta-endorphin, dinorphin, leucokinin, leutinizing hormone releasing hormone (LHRH), insulin, neurokinins, somatostatin, substance P, thyroid releasing hormone

15 (TRH) and vasopressin.

The biologically relevant molecule may be an antigen, but the antigen is not limited to a protein antigen. The antigen can also be a carbohydrate or a polynucleotide. Examples of antigenic proteins include envelope glycoproteins from viruses, animal cell membrane proteins, plant cell membrane proteins, bacterial membrane proteins and parasitic membrane proteins. Examples of a polynucleotide include a DNA or an RNA molecule. The polynucleotide can also be in the form of a plasmid DNA. The polynucleotide can be one that expresses a biologically active polypeptide, for example, an enzyme or a structural or housekeeping protein. Further, the

20 polynucleotide need not be expressed, but may be an immunogen, a ribozyme or an antisense molecule.

The biologically relevant molecule may also be a nutrient such as vitamins, minerals, fatty acids, amino acids, and saccharides. Specific examples include vitamins A, D, E, or K; minerals such as calcium, magnesium, barium, iron or zinc; polyunsaturated fatty acids or essential oils; amino acids; and saccharides such as glucose and sucrose.

The biologically relevant molecule may also be a flavor substance. Examples include flavor substances generally associated with essential oils, such as cinnamon oil, and extracts obtained from botanical sources such as herbs, citrus, spices and seeds. Oils/extracts are sensitive to degradation by oxidation, 5 and because the processing of the natural oils and extracts often involves multi-step operations, costs are generally considered to be higher. The advantage of an oil/extract-cochleate would be in the stabilization of these otherwise volatile and expensive flavor substances. Flavor-cochleates can also be incorporated into consumable food preparations as flavor enhancers.

10 The biologically relevant molecule is extracted from the source particle, cell, tissue, or organism by known methods. Biological activity of biologically relevant molecules need not be maintained. However, in some instances (e.g., where a protein has membrane fusion or ligand binding activity or a complex conformation which is recognized by the immune system), it is 15 desirable to maintain the biological activity. In these instances, an extraction buffer containing a detergent which does not destroy the biological activity of the membrane protein is used. Suitable detergents include ionic detergents such as cholate salts, deoxycholate salts and the like or heterogeneous polyoxyethylene detergents, such as Tween, BRIG or Triton.

20 Utilization of this method allows reconstitution of antigens, more specifically proteins, into the liposomes with retention of biological activities, and eventually efficient association with the cochleates. This avoids organic solvents, sonication, or extreme pH, temperature, or pressure all of which may have an adverse effect upon efficient reconstitution of the antigen in a 25 biologically active form.

Hydrogel-isolated cochleates may contain a combination of various biologically relevant molecules as appropriate.

The cochleate particles can be enteric. The cochleate particles can be placed within gelatin capsules and the capsule can be enteric coated.

30 In the preparations of the present invention certain hydrophobic materials can be added to provide enhanced absorption properties for oral delivery of biologically relevant molecules. These materials are preferably

selected from the group consisting of long chain carboxylic acids, long chain carboxylic acid esters, long chain carboxylic acid alcohols and mixtures thereof. The hydrophobic materials can be added either initially to the lipid prior to the formation of liposomes or in a later step in the form of a fat 5 vehicle such as an emulsion.

The skilled artisan can determine the most efficacious and therapeutic means for effecting treatment practicing the instant invention. Reference can also be made to any of numerous authorities and references including, for example, "Goodman & Gillman's, The Pharmaceutical Basis for Therapeutics", (6<sup>th</sup> Ed., Goodman et al., eds., MacMillan Publ. Co., New York 10 (1980)).

The invention will now be described by examples which are not to be considered as limiting the invention. In the examples, unless otherwise indicated, all ratios, percents and amounts are by weight.

15

## EXAMPLES

### **EXAMPLE 1**

#### **Preparation of Empty Hydrogel-Isolated Cochleates from Doleoylphosphatidylserine Precipitated with Calcium**

20

##### **Step 1: Preparation of Small Unilamellar Vesicles From Doleoylphosphatidylserine**

25

A solution of dioleoyl phosphatidylserine (DOPS, Avanti Polar Lipids, Alabaster, AL, USA) in chloroform (10 mg/ml) was placed in a round-bottom flask and dried to a film using a Buchi rotavapor at 35°C. The rotavapor was sterilized by flashing nitrogen gas through a 0.2  $\mu$ m filter. The following steps were carried out in a sterile hood. The dried lipid film was hydrated with de-ionized water at the concentration of 10 mg lipid/ml. The hydrated suspension was purged and sealed with nitrogen, then sonicated in a cooled bath sonicator (Laboratory Supplies Com., Inc.). Sonication was continued (for several seconds to several minutes depending on lipid quantity and nature) 30 until the suspension became clear (suspension A) and there were no liposomes apparently visible under a phase contrast microscope with a

1000x magnification. Laser light scattering (weight analysis, Coulter N4 Plus) indicated that the mean diameter was  $35.7 \pm 49.7$  nm.

Step 2: Preparation of Hydrogel-Isolated Cochleates

The liposome suspension obtained in step 1 was mixed with 40% w/w dextran-500,000 (Sigma) in a suspension of 2/1 v/v Dextran/liposome. This mixture was injected with a syringe into 15% w/w PEG-8,000 (Sigma) (PEG 8000/(suspension A)) under magnetic stirring to result in suspension B. The rate of the stirring was 800-1,000 rpm. A  $\text{CaCl}_2$  solution (100 mM) was added to the suspension to reach the final concentration of 1 mM.

Stirring was continued for one hour, and then a washing buffer containing 1 mM  $\text{CaCl}_2$  and 150 mM NaCl was added to suspension B at the volumetric ratio of 1:1. The suspension was vortexed and centrifuged at 3000 rpm, 2-4°C, for 30 min. After the supernatant was removed, additional washing buffer was added at the volumetric ratio of 0.5:1, followed by centrifugation under the same conditions. A schematic of this new method of obtaining cochleates is detailed in Fig. 1. The resultant pellet was reconstituted with the same buffer to the desired concentration. Laser light scattering (weight analysis, Coulter N4 Plus) indicates that the mean diameter for the cochleate is  $407.2 \pm 85$  nm (Fig. 2B).

20

## EXAMPLE 2

**Preparation of Empty Hydrogel-Isolated Cochleates From A Mixture of Dioleoylphosphatidylserine and 1,2-Distearoyl-sn-glycerol-3-phosphoethanolamine-n-(poly(ethylene glycol)-5000, DSPE-PEG) Precipitated with Calcium**

25 Step 1: Preparation of Small Unilamellar Vesicles

A solution of dioleoylphosphatidylserine (DOPS) and 1,2-distearoyl-sn-glycerol-3-phosphoethanolamine-n-(poly(ethylene glycol)-5000), (DSPE-PEG, Avanti Polar Lipids, Alabaster, AL, USA) in chloroform (ratio of DOPS:DSPE-PEG = 100:1, w:w) was placed in a round-bottom flask and dried to a film using a Buchi rotavapor at 35°C. The rotavapor was sterilized by flashing nitrogen gas through a 0.2  $\mu\text{m}$  filter. The following steps were

carried out in a sterile hood. The dried lipid film was hydrated with de-ionized water to a concentration of 10 mg lipid/ml. The hydrated suspension was purged and sealed with nitrogen, then sonicated in a cooled bath sonicator (Laboratory Supplies Com., Inc.). Sonication was continued 5 (for several seconds to several minutes depending on lipid quantity and nature) until the suspension became clear (suspension A) and there were no liposomes apparently visible under a phase contrast optical microscope with a 1000x magnification.

Step 2: Preparation of Hydrogel-Isolated Cochleates

10 The liposome suspension obtained in Step 1 was mixed with 40% w/w dextran-500,000 in a suspension of 2/1 v/v Dextran/liposome. This mixture was injected via a syringe into 15% w/w PEG-8,000 (PEG 8000/(suspension A)) under magnetic stirring to result in suspension B. The rate of the stirring was 800-1,000 rpm. A CaCl<sub>2</sub> solution (100 mM) was added to the suspension 15 to reach the final concentration of 1 mM.

Stirring was continued for one hour, and then a washing buffer containing 1 mM CaCl<sub>2</sub> and 150 mM NaCl was added to suspension B at the volumetric ratio of 1:1. The suspension was vortexed and centrifuged at 3000 rpm, 2-4°C, for 30 min. After the supernatant was removed, additional 20 washing buffer was added at the volumetric ratio of 0.5:1, followed by centrifugation under the same conditions. (See Fig. 1). The resulting pellet was reconstituted with the same buffer to the desired concentration. Phase contrast optical microscopy indicates the formation of uniform, very small, needle-like cochleates.

25

## EXAMPLE 3

### **Preparation of Empty Hydrogel-Isolated Cochleates from a Mixture of Dioleoylphosphatidylserine and n-octyl-beta-D-gluco-pyranoside Precipitated with Calcium**

Step 1: Preparation of Small Unilamellar Vesicles

30 A solution of dioleoylphosphatidylserine (DOPS) in chloroform was placed in a round-bottom flask and dried to a film using a Buchi rotavapor at

350C. The rotavapor was sterilized by flashing nitrogen gas through a 0.2  $\mu$ m filter. The following steps were carried out in a sterile hood. The dried lipid film was hydrated with a solution of n-octyl-beta-D-gluco-pyranoside (OCG) at 1 mg/ml at a ratio of DOPS:OCG of 10:1 w:w. The hydrated suspension 5 was purged and sealed with nitrogen, then sonicated briefly in a cooled bath sonicator.

**Step 2: Preparation of Hydrogel-Isolated Cochleates**

The suspension obtained in Step 1 was mixed with 40% w/w dextran-500,000 in a suspension of 2/1 v/v Dextran/liposome. This mixture was 10 injected via a syringe into 15% w/w PEG-8,000 (PEG 8000/(suspension A)) under magnetic stirring to result in suspension B. The rate of the stirring was 800-1,000 rpm. A  $\text{CaCl}_2$  solution (100 mM) was added to the suspension to reach the final concentration of 1 mM.

15 Stirring was continued for one hour, and then a washing buffer containing 1 mM  $\text{CaCl}_2$  and 150 mM NaCl was added to suspension B at the volumetric ratio of 1:1. The suspension was vortexed and centrifuged at 3000 rpm, 2-4 C, for 30 min. After the supernatant was removed, additional washing buffer was added at the volumetric ratio of 0.5:1, followed by centrifugation under the same conditions (see Fig. 1). The resulting pellet was 20 reconstituted with the same buffer to the desired concentration. Phase contrast optical microscopy indicates the formation of uniform, very small, needle-like cochleates.

**EXAMPLE 4**

**25 Preparation of Amphotericin B-loaded Hydrogel-Isolated Cochleates Precipitated with Calcium**

**Step 1: Preparation of Small Unilamellar AmB-Loaded, Vesicles  
from Dioleoylphosphatidylserine**

A mixture of dioleoyl phosphatidylserine (DOPS) in chloroform (10 mg/ml) and AmB in methanol (0.5mg/ml) at a molar ratio of 10:1 was 30 placed in a round-bottom flask and dried to a film using a Buchi rotavapor at 400C. The rotavapor was sterilized by flashing nitrogen gas through a 0.2  $\mu$ m

filter. The following steps were carried out in a sterile hood. The dried lipid film was hydrated with de-ionized water at the concentration of 10 mg lipid/ml. The hydrated suspension was purged and sealed with nitrogen, then sonicated in a cooled bath sonicator. Sonication was continued (for several 5 seconds to several minutes depending on lipid quantity and nature) until the suspension became clear yellow (suspension A) and there were no liposomes apparently visible under a phase contrast microscope with a 1000x magnification.

Step 2: Preparation of AmB-loaded, Hydrogel-Isolated Cochleates.

10 The liposome suspension obtained in Step 1 was then mixed with 40% w/w dextran-500,000 in a suspension of 2/1 v/v Dextran/liposome. This mixture was then injected *via* a syringe into 15% w/w PEG-8,000 (PEG 8000/(suspension A)) under magnetic stirring to result in suspension B. The rate of the stirring was 800-1,000 rpm. A CaCl<sub>2</sub> solution (100 mM) was added 15 to the suspension to reach the final concentration of 1 mM.

20 Stirring was continued for one hour, and then a washing buffer containing 1 mM CaCl<sub>2</sub> and 150 mM NaCl was added to suspension B at the volumetric ratio of 1:1. The suspension was vortexed and centrifuged at 3000 rpm, 2-4°C, for 30 min. After the supernatant was removed, additional 25 washing buffer was added at the volumetric ratio of 0.5:1, followed by centrifugation under the same conditions (*see* Fig. 1). The resulting pellet was reconstituted with the same buffer to the desired concentration. Laser light scattering (weight analysis, Coulter N4 Plus) indicated that the AmB-cochleates mean diameter was 407.3 ± 233.8 nm (Fig. 2A).

25

## EXAMPLE 5

### Preparation of Doxorubicin (DXR)-Loaded Hydrogel-Isolated Cochleates Precipitated with Calcium

Step 1: Preparation of Small Unilamellar DXR-Loaded Vesicles  
from Dioleoylphosphatidylserine

30 A mixture of dioleoylphosphatidylserine (DOPS) in chloroform (10 mg/ml) and (DXR) in methanol (0.5mg/ml) at a molar ratio of 10:1 was

placed in a round-bottom flask and dried to a film using a Buchi rotavapor at room temperature. The rotavapor was sterilized by flashing nitrogen gas through a 0.2  $\mu$ m filter. The following steps were carried out in a sterile hood. The dried lipid film was hydrated with de-ionized water at the concentration of 5 25 mg lipid/ml. The hydrated suspension was purged and sealed with nitrogen, then sonicated in a cooled bath sonicator. Sonication was continued (for several seconds to several minutes depending on lipid quantity and nature) until the suspension became clear pink (suspension A) and there were no liposomes apparently visible under phase contrast microscope with a 10 1000x magnification.

Step 2: Preparation of DXR-Loaded, Hydrogel-Isolated Cochleates

Five milliliters of the liposome suspension obtained in step 1 was mixed with 40% w/w dextran-500,000 (Sigma) in a suspension of 2/1 v/v Dextran/liposome. This mixture was injected via a syringe into 15% w/w 15 PEG-8,000 (PEG 8000/(suspension A)) under magnetic stirring to result in suspension B. The rate of the stirring was 800-1,000 rpm. A  $\text{CaCl}_2$  solution (100 mM) was added to the suspension to reach the final concentration of 1 mM.

Stirring was continued for one hour, and then a washing buffer 20 containing 1 mM  $\text{CaCl}_2$  and 150 mM NaCl was added to suspension B at the volumetric ratio of 1:1. The suspension was vortexed and centrifuged at 6400 rpm, 2-40C, for 30 min (*see* Fig. 1). The resulting pellet was reconstituted with the same buffer to the desired concentration. Laser light scattering 25 (weight analysis, Coulter N4 Plus) confirmed the formation of small DXR-cochleates.

## EXAMPLE 6

**Preparation of Cyclosporin A (CSPA)-Loaded Hydrogel-Isolated Cochleates Precipitated with Calcium**

5      Step 1: Preparation of Small Unilamellar CSPA-Loaded Vesicles  
from Dioleoylphosphatidylserine

A mixture of dioleoylphosphatidylserine (DOPS) in chloroform (10 mg/ml) and CSPA in methanol (0.5mg/ml) at a molar ratio of 10:1 was placed in a round-bottom flask and dried to a film using a Buchi rotavapor at room temperature. The rotavapor was sterilized by flashing nitrogen gas  
10     through a 0.2  $\mu$ m filter. The following steps were carried out in a sterile hood. The dried lipid film was hydrated with de-ionized water at the concentration of 10 mg lipid/ml. The hydrated suspension was purged and sealed with nitrogen, then sonicated in a cooled bath sonicator. Sonication was continued (for several seconds to several minutes depending on lipid quantity and nature)  
15     until the suspension became clear (suspension A) and there were no liposomes apparently visible under a phase contrast microscope with a 1000x magnification.

Step 2: Preparation of CSPA-Loaded, Hydrogel-Isolated Cochleates

The liposome suspension obtained in Step 1 was mixed with 40% w/w  
20     dextran-500,000 in a suspension of 2/1 v/v Dextran/liposome. This mixture was injected *via* a syringe into 15% w/w PEG-8,000 (Sigma) (PEG 8000/(suspension A)) under magnetic stirring to result in suspension B. The rate of the stirring was 800-1,000 rpm. A  $\text{CaCl}_2$  solution (100 mM) was added to the suspension to reach the final concentration of 1mM.

25     Stirring was continued for one hour, and then a washing buffer containing 1 mM  $\text{CaCl}_2$  and 150 mM NaCl was added to suspension B at the volumetric ratio of 1:1. The suspension was vortexed and centrifuged at 3000 rpm, 2-40C, for 30 min. After the supernatant was removed, additional washing buffer was added at the volumetric ratio of 0.5:1, followed by  
30     centrifugation under the same conditions (see Fig. 1).. The resulting pellet was reconstituted with the same buffer to the desired concentration. Laser

light scattering (weight analysis, Coulter N4 Plus) confirmed the formation of small CSPA-cochleates.

## EXAMPLE 7

### Preparation of Nelfinavir (NVIR)-Loaded Hydrogel-Isolated Cochleates Precipitated With Calcium

5 Step 1: Preparation of Small Unilamellar NVIR-Loaded Vesicles from Dioleoylphosphatidylserine

A mixture of dioleoylphosphatidylserine (DOPS) in chloroform (10 mg/ml) and NVIR in methanol (0.5mg/ml) at a molar ratio of 10:1 was 10 placed in a round-bottom flask and dried to a film using a Buchi rotavapor at RT. The rotavapor was sterilized by flashing nitrogen gas through a 0.2  $\mu$ m filter. The following steps were carried out in a sterile hood. The dried lipid film was hydrated with de-ionized water at the concentration of 10 mg lipid/ml. The hydrated suspension was purged and sealed with nitrogen, then 15 sonicated in a cooled bath sonicator. Sonication was continued (for several seconds to several minutes depending on lipid quantity and nature) until the suspension became clear (suspension A) and there were no liposomes apparently visible under a phase contrast microscope with a 1000x magnification.

20 Step 2: Preparation of NVIR-Loaded, Hydrogel-Isolated Cochleates

The liposome suspension obtained in Step 1 was mixed with 40% w/w dextran-500,000 in a suspension of 2/1 v/v Dextran/liposome. This mixture was injected *via* a syringe into 15% w/w PEG-8,000 (PEG 8000/(suspension A)) under magnetic stirring to result in suspension B. The rate of the stirring 25 was 800-1,000 rpm. A  $\text{CaCl}_2$  solution (100 mM) was added to the suspension to reach the final concentration of 1 mM.

Stirring was continued for one hour, and then a washing buffer containing 1 mM  $\text{CaCl}_2$  and 150 mM NaCl was added to suspension B at the volumetric ratio of 1:1. The suspension was vortexed and centrifuged at 3000 rpm, 2-40C, for 30 min. After the supernatant was removed, additional washing buffer was added at the volumetric ratio of 0.5:1, followed by 30

centrifugation under the same conditions (see Fig. 1). The resulting pellet was reconstituted with the same buffer to the desired concentration. Laser light scattering (weight analysis, Coulter N4 Plus) confirmed the formation of small NVIR-cochleates.

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## EXAMPLE 8

### **Preparation of Rifampin (RIF)-Loaded Hydrogel-Isolated Cochleates Precipitated with Calcium**

#### **Step 1: Preparation of Small Unilamellar RIF-Loaded Vesicles from Dioleoylphosphatidylserine**

10 A mixture of dioleoylphosphatidylserine (DOPS) in chloroform (10 mg/ml) and RIF in methanol (0.5mg/ml) at a molar ratio of 10:1 was placed in a round-bottom flask and dried to a film using a Buchi rotavapor at RT. The rotavapor was sterilized by flashing nitrogen gas through a 0.2  $\mu$ m filter. The following steps were carried out in a sterile hood. The dried lipid 15 film was hydrated with de-ionized water at the concentration of 10 mg lipid/ml. The hydrated suspension was purged and sealed with nitrogen, then sonicated in a cooled bath sonicator. Sonication was continued (for several seconds to several minutes depending on lipid quantity and nature) until the suspension became clear (suspension A) and there were no liposomes 20 apparently visible under a phase contrast microscope with a 1000x magnification.

#### **Step 2: Preparation of RIF-Loaded, Hydrogel-Isolated Cochleates**

25 The liposome suspension obtained in step 1 was mixed with 40% w/w dextran-500,000 (Sigma) in a suspension of 2/1 v/v Dextran/liposome. This mixture was injected via a syringe into 15% w/w PEG-8,000 (Sigma) (PEG 8000/(suspension A)) under magnetic stirring to result in suspension B. The rate of the stirring was 800-1,000 rpm. A  $\text{CaCl}_2$  solution (100 mM) was added to the suspension to reach the final concentration of 1 mM.

30 Stirring was continued for one hour, and then a washing buffer containing 1 mM  $\text{CaCl}_2$  and 150 mM NaCl was added to suspension B at the volumetric ratio of 1:1. The suspension was vortexed and centrifuged at 3000

rpm, 2-4°C, for 30 min. After the supernatant was removed, additional washing buffer was added at the volumetric ratio of 0.5:1, followed by centrifugation under the same conditions (see Fig. 1). The resulting pellet was reconstituted with the same buffer to the desired concentration. Laser light scattering (weight analysis, Coulter N4 Plus) confirmed the formation of small RIF-cochleates.

#### EXAMPLE 9

##### **Preparation of Vitamin A acid-Loaded Hydrogel-Isolated Cochleates Precipitated with Calcium**

10 Step 1: Preparation of Small Unilamellar Vitamin A-Loaded Vesicles  
from Dioleoylphosphatidylserine

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Vitamin A acid (retinoic acid) is sensitive to air oxidation and is inactivated by UV light. Vitamin A is protected when embedded into lipid bilayers. The incorporation is achieved as follows:

15 A mixture of dioleoylphosphatidylserine (DOPS) in chloroform (10 mg/ml) and Vitamin A in methanol (0.5mg/ml) at a molar ratio of lipid/vitamin A of 10:1 was placed in a round-bottom flask and dried to a film using a Buchi rotavapor at RT. The rotavapor was sterilized by flashing nitrogen gas through a 0.2  $\mu$ m filter. The following steps were carried out in a  
20 sterile hood. The dried lipid film was hydrated with de-ionized water at the concentration of 10 mg lipid/ml. The hydrated suspension was purged and sealed with nitrogen, then sonicated in a cooled bath sonicator. Sonication was continued (for several seconds to several minutes depending on lipid quantity and nature) until the suspension became clear (suspension A) and  
25 there were no liposomes apparently visible under a phase contrast microscope with a 1000x magnification.

Step 2: Preparation of Vitamin A-Loaded, Hydrogel-Isolated Cochleates

The liposome suspension obtained in Step 1 was mixed with 40% w/w dextran-500,000 in a suspension of 2/1 v/v Dextran/liposome. This mixture  
30 was injected *via* a syringe into 15% w/w PEG-8,000 in a ratio of suspension A/PEG of ½ v/v (PEG 8000/(suspension A)) under magnetic stirring to result

in suspension B. The rate of the stirring was 800-1,000 rpm. A CaCl<sub>2</sub> solution (100 mM) was added to the suspension to reach the final concentration of 1 mM.

Stirring was continued for one hour, and then a washing buffer 5 containing 1 mM CaCl<sub>2</sub> and 150 mM NaCl was added to suspension B at the volumetric ratio of 1:1. The suspension was vortexed and centrifuged at 3000 rpm, 2-40C, for 30 min. After the supernatant was removed, additional washing buffer was added at the volumetric ratio of 0.5:1, followed by centrifugation under the same conditions (see Fig. 1). The resulting pellet was 10 reconstituted with the same buffer to the desired concentration. The amount of vitamin A encapsulated in the cochleates was determined by UV absorption at 346 nm and it was found that more than 90% of the initial vitamin A was associated with the cochleates.

#### EXAMPLE 10

15 **Preparation of Polyunsaturated Fatty Acid (PFA)-Loaded Hydrogel-Isolated Cochleates Precipitated with Calcium**

PFA's are biologically relevant molecules involved in the control of the level of cholesterol in blood and are the precursors of prostaglandins. PFA's are sensitive to oxidation which limits their incorporation into food. 20 PFA's undergo, in the presence of oxygen, a series of reactions called autoxidation, leading to aldehydes and then ketones which have a fishy unpleasant odor and flavor. Embedding PFA in rigid, rolled-up, lipid bilayers helps prevent the autoxidation cascade. A general method of preparing PFA-cochleates is as follows:

25 Step 1: Preparation of Small Unilamellar PFA-Loaded Vesicles from Dioleoylphosphatidylserine

A mixture of dioleoylphosphatidylserine in chloroform (10 mg/ml) and PFA in methanol (0.5 mg/ml) at a molar ratio of 10:1 was placed in a round-bottom flask and dried to a film using a rotary evaporator at RT. The rotary 30 evaporator was sterilized by flashing nitrogen gas through a 0.2  $\mu$ m filter. The following steps were carried out in a sterile hood. The dried lipid film was

hydrated with de-ionized water at the concentration of 10 mg lipid/ml. The hydrated suspension was purged and sealed with nitrogen, then sonicated in a cooled bath sonicator. Sonication was continued (for several seconds to several minutes depending on lipid quantity and nature) until the suspension 5 became clear (suspension A) and there were no liposomes apparently visible under a phase contrast microscope with a 1000x magnification.

Step 2: Preparation of PFA-Loaded, Hydrogel-Isolated Cochleates

The liposome suspension obtained in Step 1 was mixed with 40% w/w dextran-500,000 in a suspension of 2/1 v/v Dextran/liposome. This mixture 10 was injected via a syringe into 15% w/w PEG-8,000 (PEG 8000/(suspension A)) under magnetic stirring to result in suspension B. The rate of the stirring was 800-1,000 rpm. A CaCl<sub>2</sub> solution (100 mM) was added to the suspension to reach the final concentration of 1 mM.

Stirring was continued for one hour, and then a washing buffer 15 containing 1 mM CaCl<sub>2</sub> and 150 mM NaCl was added to suspension B at the volumetric ratio of 1:1. The suspension was vortexed and centrifuged at 3000 rpm, 2-4°C, for 30 min. After the supernatant was removed, additional washing buffer was added at the volumetric ratio of 0.5:1, followed by centrifugation under the same conditions (see Fig. 1). The resulting pellet was 20 reconstituted with the same buffer to the desired concentration.

## EXAMPLE 11

### Preparation of Vanillin-Loaded Hydrogel-Isolated Cochleates Precipitated with Calcium

Step 1: Preparation of Small Unilamellar Vitamin A-Loaded Vesicles 25 from Dioleoylphosphatidylserine

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A mixture of dioleoylphosphatidylserine (DOPS) in chloroform (10 mg/ml) and Vanillin in methanol (0.5mg/ml) at a molar ratio of lipid/vanillin of 10:1 was placed in a round-bottom flask and dried to a film using a Buchi rotavapor at RT. The rotavapor was sterilized by flashing 30 nitrogen gas through a 0.2  $\mu$ m filter. The following steps were carried out in a sterile hood. The dried lipid film was hydrated with de-ionized water at the

concentration of 10 mg lipid/ml. The hydrated suspension was purged and sealed with nitrogen, then sonicated in a cooled bath sonicator. Sonication was continued (for several seconds to several minutes depending on lipid quantity and nature) until the suspension became clear (suspension A) and 5 there were no liposomes apparently visible under a phase contrast microscope with a 1000x magnification.

Step 2: Preparation of Vanillin-Loaded, Hydrogel-Isolated Cochleates

The liposome suspension obtained in Step 1 was mixed with 40% w/w dextran-500,000 in a suspension of 2/1 v/v Dextran/liposome. This mixture 10 was injected *via* a syringe into 15% w/w PEG-8,000 in a ratio of suspension A/PEG of ½ v/v (PEG 8000/(suspension A)) under magnetic stirring to result in suspension B. The rate of the stirring was 800-1,000 rpm. A CaCl<sub>2</sub> solution (100 mM) was added to the suspension to reach the final concentration of 1 mM.

15 Stirring was continued for one hour, and then a washing buffer containing 1 mM CaCl<sub>2</sub> and 150 mM NaCl was added to suspension B at the volumetric ratio of 1:1. The suspension was vortexed and centrifuged at 3000 rpm, 2-40C, for 30 min. After the supernatant was removed, additional washing buffer was added at the volumetric ratio of 0.5:1, followed by 20 centrifugation under the same conditions (see Fig. 1). The resulting pellet was reconstituted with the same buffer to the desired concentration. The amount of vanillin encapsulated in the cochleates was determined by UV absorption at 239 nm.

25

## EXAMPLE 12

**Preparation of Cinnamon Oil (CinO)-Loaded Hydrogel-Isolated Cochleates Precipitated with Calcium**

Step 1: Preparation of Small Unilamellar CinO-Loaded Vesicles from Dioleoylphosphatidylserine

30 A mixture of dioleoylphosphatidyl serine (DOPS) in chloroform (10 mg/ml) and CinO in methanol (0.5mg/ml) at a molar ratio of 10:1 was

placed in a round-bottom flask and dried to a film using a Buchi rotavapor at 40°C. The rotavapor was sterilized by flashing nitrogen gas through a 0.2  $\mu$ m filter. The following steps were carried out in a sterile hood. The dried lipid film was hydrated with de-ionized water at the concentration of 10 mg lipid/ml. The hydrated suspension was purged and sealed with nitrogen, then sonicated in a cooled bath sonicator. Sonication was continued (for several seconds to several minutes depending on lipid quantity and nature) until the suspension became clear (suspension A) and there were no liposomes apparently visible under a phase contrast microscope with a 10 1000x magnification.

Step 2: Preparation of CinO-Loaded, Hydrogel-Isolated Cochleates

The liposome suspension obtained in Step 1 was mixed with 40% w/w dextran-500,000 in a suspension of 2/1 v/v Dextran/liposome. This mixture was injected via a syringe into 15 % w/w PEG-8,000 (PEG 8000/(suspension 15 A)) under magnetic stirring to result in suspension B. The rate of the stirring was 800-1,000 rpm. A  $\text{CaCl}_2$  solution (100 mM) was added to the suspension to reach the final concentration of 1 mM.

Stirring was continued for one hour, and then a washing buffer containing 1 mM  $\text{CaCl}_2$  and 150 mM NaCl was added to suspension B at the 20 volumetric ratio of 1:1. The suspension was vortexed and centrifuged at 3000 rpm, 2-4°C, for 30 min. After the supernatant was removed, additional washing buffer was added at the volumetric ratio of 0.5:1, followed by centrifugation under the same conditions (see Fig. 1). The resulting pellet was reconstituted with the same buffer to the desired concentration.

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### EXAMPLE 13

**Preparation of DNA-Loaded Hydrogel-Isolated Cochleates Precipitated with Calcium**

Step 1: Preparation of Small Unilamellar DNA-Loaded Vesicles  
from Dioleoylphosphatidylserine

30 A solution of dioleoylphosphatidylserine in chloroform (10 mg/ml) was placed in a round-bottom flask and dried to a film using a Buchi rotavapor

at RT. The rotavapor was sterilized by flashing nitrogen gas through a 0.2  $\mu$ m filter. The following steps were carried out in a sterile hood. The dried lipid film was hydrated with a solution of pCMV-beta-gal-DNA in TE buffer (at 1 mg/ml) to reach a concentration of DOPS:DNA of 10:1 and a concentration 5 of 10 mg lipid/ml. The hydrated suspension was purged and sealed with nitrogen, then vortexed for several minutes.

Step 2: Preparation of DNA-Loaded, Hydrogel-Isolated Cochleates

The DNA/liposome mixture was mixed with 40% w/w dextran-500,000 in a suspension of 2/1 v/v Dextran/liposome. This mixture 10 was injected *via* a syringe into 15% w/w PEG-8,000 (PEG 8000/(suspension A)) under magnetic stirring to result in suspension B. The rate of the stirring was 800-1,000 rpm. A  $\text{CaCl}_2$  solution (100 mM) was added to the suspension to reach the final concentration of 1 mM.

Stirring was continued for one hour, and then a washing buffer 15 containing 1 mM  $\text{CaCl}_2$  and 150 mM NaCl was added to suspension B at the volumetric ratio of 10:1. The suspension was vortexed and centrifuged at 3000 rpm, 2-4 C, for 30 min. After the supernatant was removed, additional washing buffer was added at the volumetric ratio of 5:1, followed by centrifugation under the same conditions (*see* Fig. 1). The resulting pellet was 20 reconstituted with the same buffer to the desired concentration.

#### EXAMPLE 14

**Preparation of Empty Hydrogel-Isolated Cochleates  
Precipitated with Zinc**

Step 1: Preparation of Small Unilamellar Vesicles  
25 from Dioleoylphosphatidylserine

A solution of dioleoylphosphatidylserine (DOPS) in chloroform (10 mg/ml) was placed in a round-bottom flask and dried to a film using a Buchi rotavapor at 35°C. The rotavapor was sterilized by flashing nitrogen gas through a 0.2  $\mu$ m filter. The following steps were carried out in a sterile 30 hood. The dried lipid film was hydrated with de-ionized water at the concentration of 10 mg lipid/ml. The hydrated suspension was purged and

sealed with nitrogen, then sonicated in a cooled bath sonicator. Sonication was continued (for several seconds to several minutes depending on lipid quantity and nature) until the suspension became clear (suspension A) and there were no liposomes apparently visible under a phase contrast microscope 5 with a 1000x magnification.

Step 2: Preparation of Hydrogel-Isolated Cochleates

The liposome suspension obtained in step 1 was mixed with 40% w/w dextran-500,000 in a suspension of 2/1 v/v Dextran/liposome. This mixture was injected via a syringe into 15% w/w PEG-8,000 (PEG 8000/(suspension 10 A)) under magnetic stirring to result in suspension B. The rate of the stirring was 800-1,000 rpm. A ZnCl<sub>2</sub> solution (100 mM) was added to the suspension to reach the final concentration of 1 mM.

Stirring was continued for one hour, and then a washing buffer containing 1 mM ZnCl<sub>2</sub> and 150 mM NaCl was added to suspension B at the 15 volumetric ratio of 1:1. The suspension was vortexed and centrifuged at 3000 rpm, 2-40C, for 30 min. After the supernatant was removed, additional washing buffer was added at the volumetric ratio of 0.5:1, followed by centrifugation under the same conditions (see Fig. 1). The resulting pellet was reconstituted with the same buffer to the desired concentration. Laser light 20 scattering (weight analysis, Coulter N4 Plus) confirmed the formation of small cochleates.

## EXAMPLE 15

### Preparation of Amphotericin B-Loaded Hydrogel-Isolated Cochleates Precipitated with Zinc

25 Step 1: Preparation of Small Unilamellar AmB-Loaded Vesicles from Dioleoylphosphatidylserine

A mixture of dioleoyl phosphatidylserine (DOPS) in chloroform (10 mg/ml) and AmB in methanol (0.5 mg/ml) at a molar ratio of 10:1 was placed in a round-bottom flask and dried to a film using a Buchi rotavapor at 30 400C. The rotavapor was sterilized by flashing nitrogen gas through a 0.2  $\mu$ m filter. The following steps were carried out in a sterile hood. The dried lipid

film was hydrated with de-ionized water at the concentration of 10 mg lipid/ml. The hydrated suspension was purged and sealed with nitrogen, then sonicated in a cooled bath sonicator. Sonication was continued (for several seconds to several minutes depending on lipid quantity and nature) until the 5 suspension became clear yellow (suspension A) and there were no liposomes apparently visible under a phase contrast microscope with a 1000x magnification.

Step 2: Preparation of AmB-Loaded, Hydrogel-Isolated Cochleates

The liposome suspension obtained in Step 1 was mixed with 40% w/w 10 dextran-500,000 in a suspension of 2/1 v/v Dextran/liposome. This mixture was injected via a syringe into 15% w/w PEG-8,000 (PEG 8000/(suspension A)) under magnetic stirring to result in suspension B. The rate of the stirring was 800-1,000 rpm. A ZnCl<sub>2</sub> solution (100 mM) was added to the suspension to reach the final concentration of 1 mM.

15 Stirring was continued for one hour, and then a washing buffer containing 1 mM ZnCl<sub>2</sub> and 150 mM NaCl was added to the suspension B at the volumetric ratio of 1:1. The suspension was vortexed and centrifuged at 3000 rpm, 2-40C, for 30 min. After the supernatant was removed, additional washing buffer was added at the volumetric ratio of 0.5:1, followed by 20 centrifugation under the same conditions (see Fig. 1). The resultant pellet was reconstituted with the same buffer to the desired concentration. Laser light scattering (weight analysis, Coulter N4 Plus) confirmed the formation of small AmB-Zn-cochleates.

#### EXAMPLE 16

25 Microscopic Observation of Hydrogel-Isolated Cochleates

Optical microscopic study was performed stepwise alone with the preparation procedure in order to gain some mechanistic details of the formation of the hydrogel-isolated cochleates.

30 The microscopic images seen in Figs. 3A, 3B and 4A-4F show the morphological changes at each preparation step of AmB loaded hydrogel-isolated cochleates precipitated with Ca<sup>2+</sup> ions. When the AmB/liposome-

dextran mixture was dispersed into PEG solution, phase separation resulted as shown by Fig. 3A. Partition of the liposomes favored the dispersed dextran phase as indicated by a yellow color of AmB. This partitioning ensures that liposomes are isolated in each dextran particle. Addition of Calcium ions into 5 the continued phase (PEG) resulted in formation of precipitates in the dispersed phase. As the final product, small needle-shape cochleates were formed and observed under the microscope, these cochleates opened into unilamellar vesicles upon addition of EDTA and chelation of the calcium (Figs. 4A and 4B). The needle-shaped morphology was confirmed by 10 scanning electron microscopy after freeze-fracture (Fig. 5). Similar microscopic images were obtained for empty and AmB-Zn-precipitated hydrogel-isolated cochleates (Figs. 4C and 4D) and empty Zn-precipitated hydrogel-isolated cochleate (Figs. 4E and 4F).

#### EXAMPLE 17

15 **Antifungal Activity of Hydrogel-Isolated Cochleates  
Loaded with Amphotericin B, In Vitro**

Growth Inhibition of *Candida albicans*

An *in vitro* yeast susceptibility assay was performed comparing the inhibitory and lethal effects of AmB-cochleates, AmBisomes (liposomal 20 formulation of AmB) and AmB/DMSO. Five colonies of freshly growing *Candida albicans* were selected from a YPD agar plate (from a 48 hour culture) and added to 2 ml of 2x YPD broth, pH 5.7. The OD<sub>590</sub> of this stock culture was measured and the yeast density was adjusted to OD<sub>590</sub> = 0.1 and 0.1 ml of this suspension added to each well of a 96 well plate.

25 AmB/cochleates, AmB/DMSO and AmBisomes were added to 96 well plates to a final concentration of 0.078, 0.156, 0.3125, 0.625, 1.25 and 2.5  $\mu$ g/ml of AmB. The 96 well plates were incubated at 37°C with gentle shaking and cell density was measured on a 96 well plate reader (Molecular Devices Spectramax 340) at 0, 2, 4, 6, 24 and 30 hours. Fig. 6 shows that 30 AmB-cochleates have a greater growth inhibitory effect than AmBisomes (liposomal formulation of AmB).

Fungicidal Effect of Hydrogel-Isolated Cochleates Loaded with Amphotericin B

Aliquots of yeast cells (50  $\mu$ l) were removed from the 96 well plates and serially diluted (up to 1:10000 for plating onto agar plates) and counted 5 using a hemocytometer. Fifty  $\mu$ l of the diluted yeast cells were plated onto YPD agar plates and incubated for 24 hours at 37°C. Yeast colonies were counted using a BioRad Fluor-S Multi-Imager equipped with Quanitity One $\infty$  software.

Yeast cells treated with AmBisome, AmB/DMSO and AmB/cochleates 10 (0.625  $\mu$ g AmB/ml) were examined for the ratio of colony forming units to total cell number after 30 hours of incubation. The results show that the AmB/cochleates had the greatest lethal effect on the yeast cells compared to the other antifungal agents tested. There was nearly 0% yeast viability after treatment with the AmB-cochleates and 12% yeast viability after treatment 15 with AmB/DMSO. The AmBisome was not as effective, resulting in 52% yeast viability (Fig. 7).

Macrophage Protection with AmB cochleates

Particle scavenging cells, such as macrophage, are the first line of defense against many microbial infections. However, many microbes, which 20 induce severe human clinical infections, have been shown to infect macrophage and avoid destruction.

It is possible that *in vivo*, macrophage play an important role in the uptake of cochleates, via an endocytotic mechanism. Since macrophage also play an important role in the host defense and clearance of fungi and parasites, 25 it is important to study the interaction between macrophage and cochleates.

The following examples indicate that the cochleates are taken up by macrophage. Large doses of AmB delivered to the macrophage were found to be non-toxic and remained within the macrophage in a biologically active 30 form. AmB cochleates provided protection for the macrophage against infection by *Candida albicans* when administered prior to or after fungal infection.

*Prophylactic dose regime:* J774A.1 macrophage (M) were subcultured into a 96-well plate at a concentration of  $1 \times 10^5$  cells/ml in DMEM +10% FBS. One-hundred Π AmB cochleates (AmBc 0.2, 0.6, 1.25, and 2.5  $\mu$ g AmB/ml), Fungizone, or empty cochleates (EC at 2, 6, 12.5, and 25  $\mu$ g lipid/ml) were 5 added at the specified concentration. Plates were incubated overnight at 37°C and 5% CO<sub>2</sub>. 24 hours later, the medium was replaced. This step was performed twice. *Candida albicans* (CA) was added to the plate at a concentration of  $2.5 \times 10^3$  cells/ml, a ratio of 1:200 with respect to the macrophage. Plates were incubated overnight under the conditions stated 10 above.

Following the 24 hr incubation, the plates were removed and observed. Medium was pipetted vigorously to remove and disrupt the cells, 25  $\mu$ l of this suspension was placed onto Sabouraud Dextrose Agar plates, and then placed in a dry incubator overnight at 37°C. *Candida albicans* CFU's were counted 15 the following day. The data in Fig. 8A suggest that AmB cochleate loaded macrophage are very effective at killing the fungal cells.

*Post-infection dose regime:* J774A.1 macrophage (M) were subcultured into a 96-well plate and then incubated overnight. Following incubation, the macrophage were infected with CA at a ratio of 200:1, then 20 subsequently AmBc, Fungizone or EC was added at the specified concentrations. Twenty-four hours later, the cell cultures were observed and CFU's determined as described above.

When M were challenged with CA and subsequently dosed with AmB cochleates, the CFU count was again nearly zero. These results indicate that 25 macrophage engulf and concentrate AmB cochleate, as macrophage were protected against *Candida albicans* challenge after AmB cochleate had been washed off (Fig. 8B).

In contrast, Fungizone, (AmB in deoxycholate), the most popular 30 clinical form of AmB was extremely toxic and lethal to the macrophage *in vitro*. Within 5 hours of administration, there was a large amount of cellular debris found in the petri dish, with no signs of viable macrophage.

Microscopic observation reveals the AmB cochleates are not toxic to the macrophage even at the highest doses studied. The AmB cochleates are accumulated at high levels resulting in large distended vacuoles. After washing of the macrophage and incubating again for 24 hours, most of the 5 vacuoles had returned to the normal shape and size, yet a few were noticeably enlarged. A few macrophage were even noticed to be "moving" with the enlarged vacuoles. AmB cochleates are concentrated within the vacuoles and it is probable that AmB is released gradually over time.

#### EXAMPLE 18

10 **Evaluation of Tissue Penetration of AmB after IV Administration  
of Amphotericin B Hydrogel-Isolated Cochleates**

Tissue penetration of amphotericin B has been evaluated after IV administration. Groups (n=5) of C57BL/6 mice (20–23 g) were given IV (0.625 mg/kg) AmB cochleates (0.05 ml/ 20 g) with a ½ cc U 100 insulin 15 syringe with a 18 g ½ needle size. At predetermined sacrifice times (2, 5, 10, 20 and 40 min, 1, 2, 3, 4, 6, 8, 12, 24, 36 and 48 hrs), animals were given anesthesia, their blood was collected via cardiac puncture, and then, the animals were euthanized and dissected. Tissues of interest were removed (brain, lung, liver, spleen, kidneys, heart, fat, stomach, stomach contents, 20 intestine and intestinal contents) and weighed. For analysis of AmB, samples were mixed with extraction solvent (10% methanol, 35% water, 55% ethanol), homogenized, sonicated and centrifuged. A 90  $\mu$ l aliquot of supernatant was transferred into a micro vial, injected into the HPLC system in a Nova-Pak C- 18 column (3.9 x 150 mm, 4  $\mu$ m particle size), and kept at 40°C. 25 Amphotericin B was eluted at a flow rate of 0.5 ml/min with 29% methanol, 30% acetonitrile and 41% 2.5 mM EDTA and then detected at 408 nm. The concentration of AmB was calculated with the help of an external standard curve.

In Fig. 9 the tissue exposure after a single IV dose of AmB cochleates 30 is shown. Large penetration of key tissues like liver, spleen and kidney can be observed.

**EXAMPLE 19****Oral Delivery of AmB Mediated by Hydrogel-Isolated Cochleates Loaded with AmB****Single Dose Regime**

5       Oral availability of the hydrogel-isolated cochleates loaded with AmB has been examined by intragastric administration of the formulation of Example 4 to overnight fasting, C57BL16 mice (20-23g). 1/10 ml of the formulation at the dose of 10 mg/kg was administrated to 9 mice. Three mice from each group were sacrificed at 1, 6 and 24 hrs post administration  
10       followed by analysis of AmB level in organs and tissues.

15       Tissue and blood samples were processed as follows: tissues were diluted 1/20 or 1/10 by addition of extraction solvent (H<sub>2</sub>O 35%, methanol 10%, ethanol 55% w/w/w nv/v/v) and homogenized with an Ultra-Turrex® device. A 0.5 ml aliquot was taken, sonicated for 1 min and centrifuged at 7260 rpm for 12 min at 4°C. Supernatant was transferred to an HPLC micro-vial and 30  $\mu$ l was injected on a C-18, 3.9 x 150 mm, 4  $\mu$ m particle sized analytical column with a flow rate of 0.5 ml, at 40°C. Concentration of AmB detected at 408 nm was calculated with the help of an external calibration curve.

20       Fig. 10 shows the time profile of AmB in the tissues over a period of time of 24 hrs. Although only three time points are plotted, accumulation in key tissues (liver, lungs, spleen and kidneys) can be seen.

**Multiple Dose Regime**

25       Two other groups of mice received a 10 mg/kg/day oral multiple dose regime for ten days and one group was sacrificed 24 hrs after the last dose and the other group 20 days after the last dose received. At the predetermined time points mice were anesthetized, sacrificed and dissected for tissue collection. Tissues were processed as in the single dose regime and the AmB level was determined by HPLC. Results from 24 hr after the 10<sup>th</sup> dose are depicted in  
30       Fig. 11 and show that hydrogel-isolated cochleates allow the delivery of AmB from the gastrointestinal tract at therapeutic levels.

## EXAMPLE 20

### **Correlation Between Biodistribution in Healthy and Infected Mice and the Level of *Candida albicans* in Tissue after Oral Administration**

Fig. 12 shows the relationship between tissue levels of Amphotericin B (5  $\mu$ g/g tissue on left scale) and efficacy as decrease of *Candida albicans* infection (CFU/g on the right scale) after oral administration of AmB-cochleates.

After oral administration of 10 mg/kg/day for 10 consecutive days to healthy mice, AmB presented high levels in kidneys followed by lungs, 10 spleen, liver and brain, which shows much lower levels than the other tissues. It has been shown that disease state affects pharmacokinetics of drugs at different levels. This phenomenon can be seen clearly in the graph: AmB in tissue reaches lower levels in *Candida albicans* infected mice after oral administration of 10 mg/kg/day (same dose) for 15 days, 5 more doses than 15 the healthy group. It also shows a change in the distribution pattern where the lungs are the target tissue with lowest levels.

Oral administration of an AmB cochleate formulation at 10 mg/kg/day for 15 days provided high efficacy. The decrease in CFU/g in kidney tissue is about 3.5 logs for the cochleate formulation. In lungs, AmB cochleate 20 formulations completely eradicate *Candida albicans* and clear the lungs of fungal infection. It is clear that the cochleate delivery system provides a high level of AmB in infected animals, this correlates with the higher efficiency seen in the cochleate formulation, indicating that AmB-cochleates are a suitable vehicle for oral treatment of systemic Candidiasis.

25 In addition, orally administered AmB-cochleates were non-toxic even at the highest dose of 50 mg/kg (no lesions were found in kidneys, GI tract and other organs of mice given 10, 20 and 50 mg/kg of AmB-cochleates). This high dose (50 mg/kg) is equivalent to 100 times the lowest dose (0.5 mg/kg) that showed 100% of survival in the *Candida* infected mouse model.

What is claimed is:

1. A method for preparing lipid-based cochleates comprising:
  - a) providing an aqueous suspension of liposomes, and at least one biologically relevant molecule selected from the group consisting of a nutrient and a flavor substance;
  - b) mixing the liposome suspension with a polymer A to make a liposome/Polymer A suspension;
  - c) adding the liposome/polymer A suspension into a solution comprising polymer B, wherein polymer A and polymer B are immiscible, thereby creating a two-phase polymer system;
  - d) adding a solution of a cationic moiety to the two-phase polymer system; and
  - e) washing the two-phase polymer system to remove the polymers.
2. A method according to claim 1, wherein the nutrients are at least one member selected from the group consisting of vitamins, minerals, fatty acids, amino acids, and saccharides.
3. A method according to claim 2, wherein the vitamins are at least one member selected from the group consisting of vitamins A, D, E, and K.
4. A method according to claim 2, wherein the minerals are at least one member selected from the group consisting of calcium, magnesium, barium, iron and zinc.
5. A method according to claim 2, wherein the saccharides are at least one member selected from the group consisting of glucose and sucrose.

6. A method according to claim 1, wherein the flavor substance is at least one member selected from the group consisting of botanical essential oils and extracts.
7. A method according to claim 6, wherein the flavor substance is cinnamon oil.
8. A method according to claim 6, wherein the extracts are at least one member selected from the group consisting of an extract of an herb, a citrus, a spice, and a seed.
9. A method according to any one of the preceding claims wherein the aqueous suspension of liposomes is provided by sonication or microfluidization.
10. A method according to any one of the preceding claims wherein the liposome/polymer A suspension is made by injection.
11. A method according to any one of the preceding claims wherein the liposome/polymer A suspension is added at a controlled rate of about 0.1 ml/min. to 50 ml/min.
12. A method according to any one of the preceding claims wherein the liposome/polymer A suspension is added at a controlled rate of about 1 to 10 ml/min.

13. A method according to any one of the preceding claims wherein the liposomes are formed of lipid, comprising a negatively charged lipid.
14. A method according to claim 13 wherein the negatively charged lipid is a negatively charged phospholipid.
15. A method according to claim 13 or 14, wherein the negatively charged phospholipid is selected from the group consisting of phosphatidylserine, phosphatidylinositol, phosphatidic acid, and phosphatidyl glycerol.
16. A method according to claims 13,14, or 15, wherein the lipid comprises a minor amount of other lipids.
17. A method according to claim 16, wherein the other lipids are one or more zwitterionic lipids.
18. A method according to claim 16, wherein the other lipids are one or more cationic lipids.
19. A method according to claim 16, wherein the other lipids are one or more polycationic lipids.
20. A method according to claim 16, wherein the other lipids are one or more neutral lipids capable of forming hydrogen bonds to biologically active molecules.

21. A method according to claim 20, wherein the neutral lipids are one or more PEGylated lipids.
22. A method according to any one of the preceding claims wherein the cochleates are formed using small unilamellar liposomes.
23. A method of any of the preceding claims wherein the aqueous suspension of liposomes is formed using unilamellar liposomes.
24. A method according to any one of the preceding claims wherein the aqueous suspension of liposomes is formed using loaded liposomes loaded with the biologically relevant molecule.
25. A method according to any one of the preceding claims wherein the aqueous suspension of liposomes comprises the biologically relevant molecule, whereby the cochleates also comprise the biologically relevant molecule.
26. A method according to claim 25 which comprises the preliminary step of forming the liposome suspension by forming a film comprising a mixture of the biologically relevant molecule and lipid and contacting the film with an aqueous phase to form the aqueous suspension of small unilamellar liposomes.
27. A method according to claim 26 in which the biologically relevant molecule is present in the aqueous phase.

28. A method according to claim 27 comprising the preliminary step of forming liposomes in which a film of lipid is contacted with aqueous phase containing the biologically relevant molecule to form the aqueous suspension of liposomes.

29. A method according to claim 26 including a preliminary step in which a suspension of empty liposomes is mixed with the biologically relevant molecule to form the said liposome suspension.

30. A method according to claim 27 wherein the biologically relevant molecule bears a charge.

31. A method according to claim 30, wherein the biologically relevant molecule is positively charged.

32. A method according to claim 30, wherein the biologically relevant molecule is negatively charged.

33. A method according to any one of the preceding claims wherein the biologically relevant molecule is biologically active.

34. A method for producing lipid-based cochleates comprising the steps of:

- providing an aqueous suspension comprising a detergent-lipid mixture;
- mixing the detergent-lipid suspension with polymer A to make a lipid/polymer A suspension;

- c) adding the detergent-lipid/polymer A suspension into a solution comprising polymer B, wherein polymer A and B are immiscible, thereby creating a two phase polymer system;
- d) adding a solution of cationic moiety to the two phase polymer system;
- e) washing the two phase polymer system to remove the polymer; and
- f) providing, in step a), at least one biologically relevant molecule selected from the group consisting of a nutrient or a flavor substance.

35. A method for producing lipid-based cochleates according to claim 34, wherein the detergent is octyl glucoside.

36. A method for producing lipid-based cochleates according to claim 34, wherein the biologically relevant molecule is biologically active.

37. A method according to claim 34, wherein the nutrients are at least one member selected from the group consisting of vitamins, minerals, fatty acids, amino acids, and saccharides.

38. A method according to claim 34, wherein the vitamins are at least one member selected from the group consisting of vitamins A, D, E, and K.

39. A method according to claim 34, wherein the minerals are at least one member selected from the group consisting of calcium, magnesium, barium, iron and zinc.

40. A method according to claim 34, wherein the saccharides are at least one member selected from the group consisting of glucose and sucrose.
41. A method according to claim 34, wherein the flavor substance is at least one member selected from the group consisting of botanical essential oils and extracts.
42. A method according to claim 41, wherein the flavor substance is cinnamon oil.
43. A method according to claim 41, wherein the extracts are at least one member selected from the group consisting of an extract of an herb, a citrus, a spice, and a seed.
44. A method according to any one of the preceding claims wherein polymer A is at least one member selected from the group consisting of dextran and polyethylene glycol.
45. A method according to any one of the preceding claims wherein the concentration of polymer A in the two phase polymer system ranges from 2 to 20 % w/w.
46. A method according to any one of the preceding claims wherein polymer B is at least one member selected from the group consisting of polyvinylpyrrolidine, polyvinylalcohol, Ficoll, polyvinyl methyl ether, and polyethylene glycol.
47. A method according to any one of the preceding claims wherein the concentration of polymer B in the two phase system is in the range of 2 to 20% w/w.

48. A method according to any one of the preceding claims wherein the two-phase polymer solution is at least one member selected from the group consisting of dextran/polyethylene glycol, dextran/polyvinylpyrrolidone, dextran/polyvinylalcohol, dextran/Ficoll and polyethylene glycol/polyvinyl methyl ether.

49. A method according to any one of the preceding claims wherein the cationic moiety is an element capable of forming divalent ions.

50. A method according to any one of the preceding claims wherein the cationic moiety is a structure capable of chelating and bridging negatively charged lipids.

51. A method according to any one of the preceding claims wherein the cationic moiety is a polycationic lipid.

52. A method according to any one of the preceding claims wherein the cationic moiety comprises a di- or higher valent ion.

53. A method according to any one of the preceding claims wherein the cationic moiety comprises a di- or higher valent metal ion.

54. A method according to claim 53, wherein the metal ion is added as a salt of an inorganic acid, preferably when the salt is calcium chloride, zinc chloride, or cobalt chloride.

55. A method according to claims 53 or 54, wherein the metal ion is selected from the group consisting of  $\text{Ca}^{++}$ ,  $\text{Zn}^{++}$ ,  $\text{Ba}^{++}$  and  $\text{Mg}^{++}$ .
56. A method according to any one of the preceding claims wherein the cochleates are small-sized cochleates.
57. A method according to any one of the preceding claims, wherein the size of the cochleates is less than 1 micron.
58. A method according to any one of the preceding claims in which the washing step comprises centrifuging the two-phase polymer system to separate the cochleate precipitate, removing the supernatant containing the polymer, resuspending the precipitate in a washing buffer, centrifuging the washed precipitate, and optionally repeating the resuspension and centrifugation steps one or more times.
59. A method according to claim 58, wherein the washing buffer contains dissolved cationic moiety.
60. A method according to claim 59 in which the cationic moiety comprises di- or higher- valent ions.
61. A method according to claim 60 in which the di- or higher- valent ions are metal ions.

62. A method according to claim 61 in which the metal ions are selected from calcium and zinc.
63. A method according to any of claims 59 to 62 in which the cationic moiety is present in the washing buffer at a concentration of at least 1mM.
64. Cochleates containing a biologically relevant molecule prepared according to any one of claims 1 to 63.
65. Cochleates containing a biologically relevant molecule according to claim 64 having a mean particle size less than 1 micron.
66. A method according to any one of the preceding claims in which the cochleates are suspended in a medium which contains a salt.
67. A method according to claim 66, wherein the medium contains a salt selected from the group consisting of calcium chloride, zinc chloride, cobalt chloride, sodium chloride, sodium sulfate, potassium sulfate, and sodium carbonate.
68. A method according to any one of the preceding claims in which the cochleates are suspended in a medium which contains a polymer.
69. A method according to claim 68, wherein the medium contains a polymer selected from the group consisting of pluronic and polyethylene glycols.

70. A method according to any one of the preceding claims wherein the biologically relevant molecule is organic.

71. A method according to any one of the preceding claims wherein the biologically relevant molecule is inorganic.

72. A method according to any one of the preceding claims wherein the biologically relevant molecule is a monomer.

73. A method according to any one of the preceding claims wherein the biologically relevant molecule is a polymer.

74. A method according to any one of the preceding claims wherein the biologically relevant molecule is hydrophilic.

75. A method according to any one of the preceding claims wherein the biologically relevant molecule is amphiphilic.

76. A method according to any one of the preceding claims wherein the biologically relevant molecule is hydrophobic.

77. A method according to anyone of the preceding claims wherein the biologically relevant molecule is endogenous to a host organism.

78. A method according to anyone of the preceding claims wherein the biologically relevant molecule is naturally occurring.

79. A method according to anyone of the preceding claims wherein the biologically relevant molecule is synthesized *in vitro*.

80. A cochleate composition comprising:

- a) a biologically relevant molecule;
- b) a negatively charged first lipid; and
- c) a divalent cation or higher valent cation,

wherein the particle size of the cochleate is less than one micron.

81. The cochleate composition according to claim 80, wherein the biologically relevant molecule bears a charge.

82. The cochleate composition according to claim 81, wherein the biologically relevant molecule is positively charged.

83. The cochleate composition according to claim 81, wherein the biologically relevant molecule is negatively charged.

84. The cochleate composition according to claim 80, wherein the biologically relevant molecule is at least one member selected from the group consisting of a nutrient or flavor substance.

85. The cochleate composition according to claim 84, wherein the nutrient is at least one member selected from the group consisting of vitamins, minerals, fatty acids, amino acids, and saccharides.
86. The cochleate composition according to claim 85, wherein the vitamin is at least one member selected from the group consisting of vitamins A, D, E, and K.
87. The cochleate composition according to claim 85, wherein the mineral is at least one member selected from the group consisting of calcium, magnesium, barium, iron and zinc.
88. The cochleate composition according to claim 85, wherein the fatty acid is at least one member selected from the group consisting of polyunsaturated or saturated fatty acids.
89. The cochleate composition according to claim 84, wherein the flavor substance is at least one member selected from the group consisting of botanical essential oils and extracts.
90. The cochleate composition according to claim 89, wherein the extracts are from at least one member selected from the group consisting of an herb, a citrus, a spice and a seed.
91. The cochleate composition according to claim 80, wherein the negatively charged lipid is comprised of phosphatidylserine.

92. The cochleate composition according to claim 80, wherein the cochleate composition further comprises a minor amount of a second lipid.
93. The cochleate composition according to claim 92, wherein the second lipid is a zwitterionic lipid.
94. The cochleate composition according to claim 92, wherein the second lipid is a cationic lipid.
95. The cochleate composition according to claim 92, wherein the second lipid comprises lipid capable of forming hydrogen bonds to the biologically relevant molecule.
96. The cochleate composition according to claim 92, wherein the second lipid is PEGylated lipid.
97. The cochleate composition according to claim 80, wherein the di- or higher-valent ions are metal ions.
98. The cochleate composition according to claim 97, wherein the divalent metal ions are selected from the group consisting of calcium, zinc, barium, and magnesium.

99. A nutrient or flavor substance comprising an effective amount of the cochleate composition of in any one of claims 80-98, and a pharmaceutically acceptable carrier.

100. A method of treatment for a nutrient deficiency comprising administering to a human or animal host the cochleate composition according to any one of claims 80-98, wherein the biologically relevant molecule is a nutrient.

101. The method of treatment according to claim 100, wherein the administration is by a mucosal or a systemic route.

102. The method of treatment according to claim 101, wherein the administration is a mucosal route selected from the group consisting of oral, intranasal, intraocular, intraanal, intravaginal, parenteral and intrapulmonary.

103. The method of treatment according to claim 102, wherein the administration is by a systemic route selected from the group consisting of intravenous, intramuscular, subcutaneous, transdermal and intradermal.

104. A method of packaging a flavor substance comprising encochleating the flavor substance.

105. The use of the composition of claims 80 to 98 to hide or to supply a flavor, wherein the biologically relevant molecule is a flavor.

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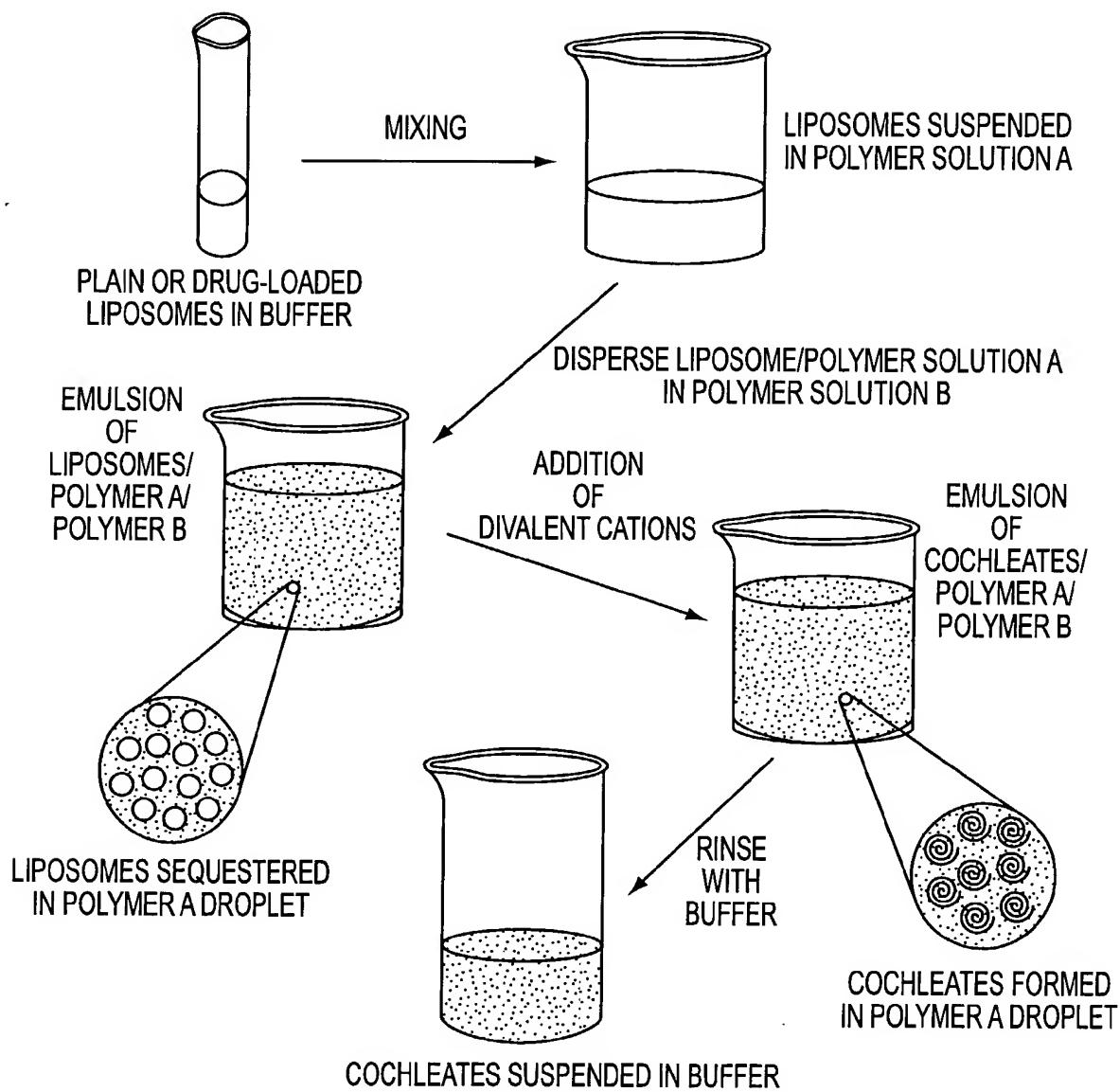


FIG. 1

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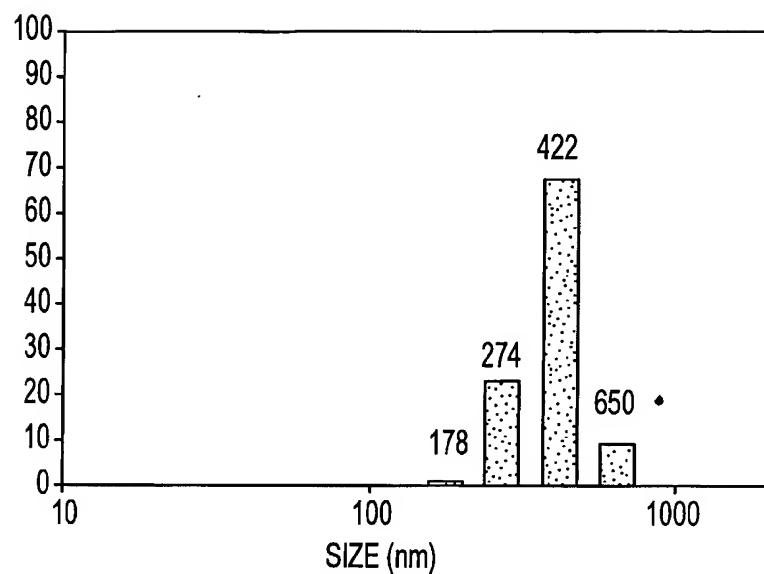


FIG. 2A

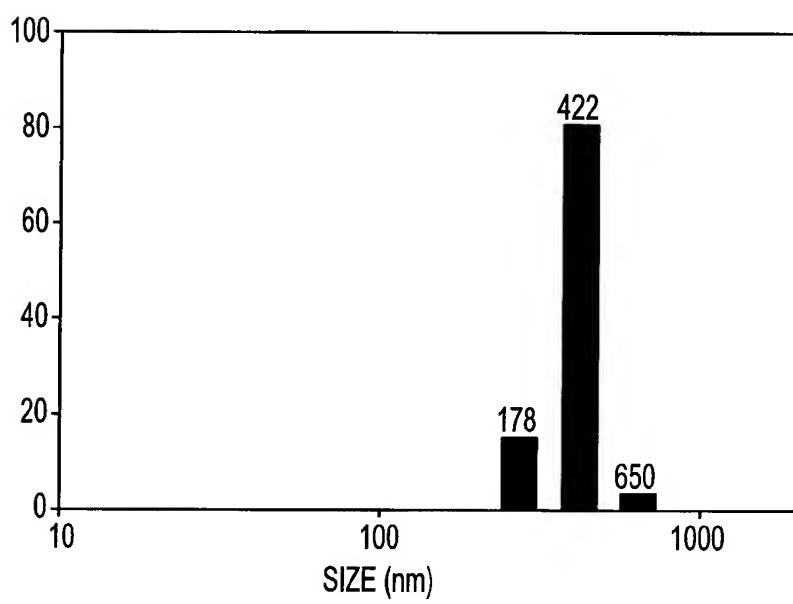


FIG. 2B

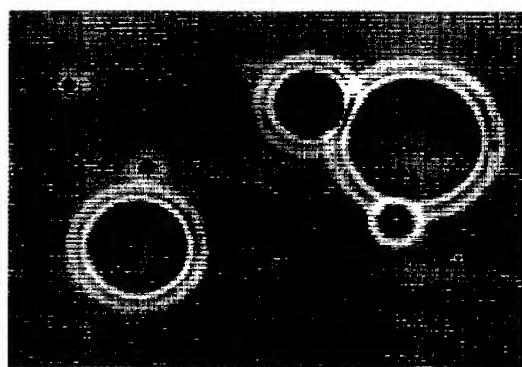


FIG. 3A

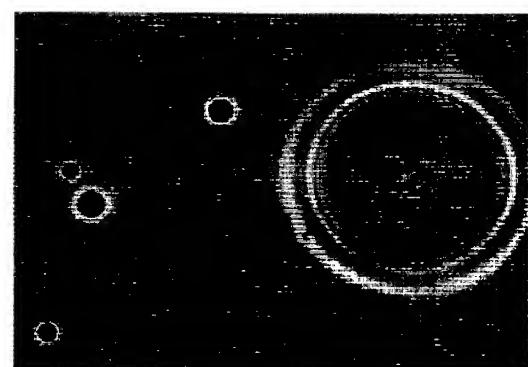


FIG. 3B



FIG. 4A

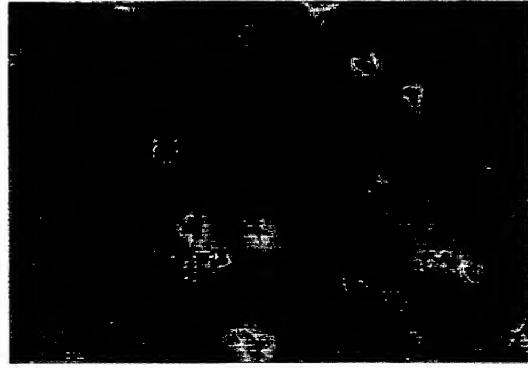


FIG. 4B

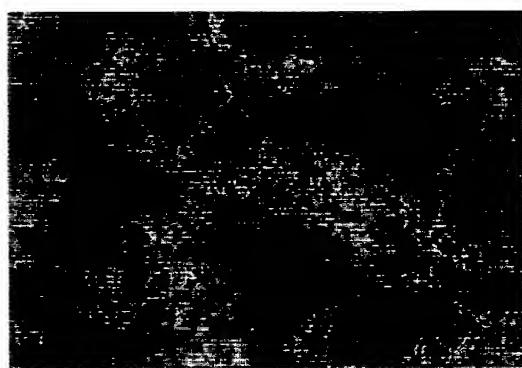


FIG. 4C

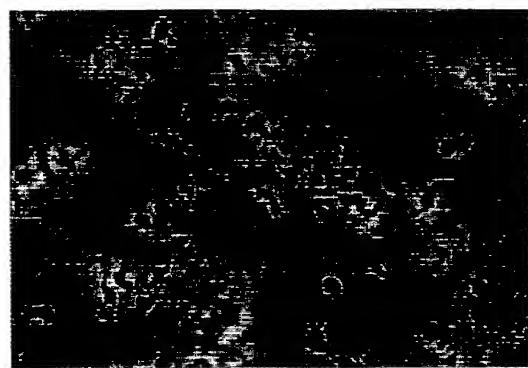


FIG. 4D



FIG. 4E

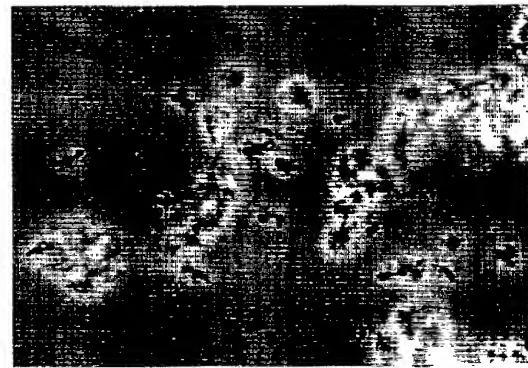


FIG. 4F



FIG. 5

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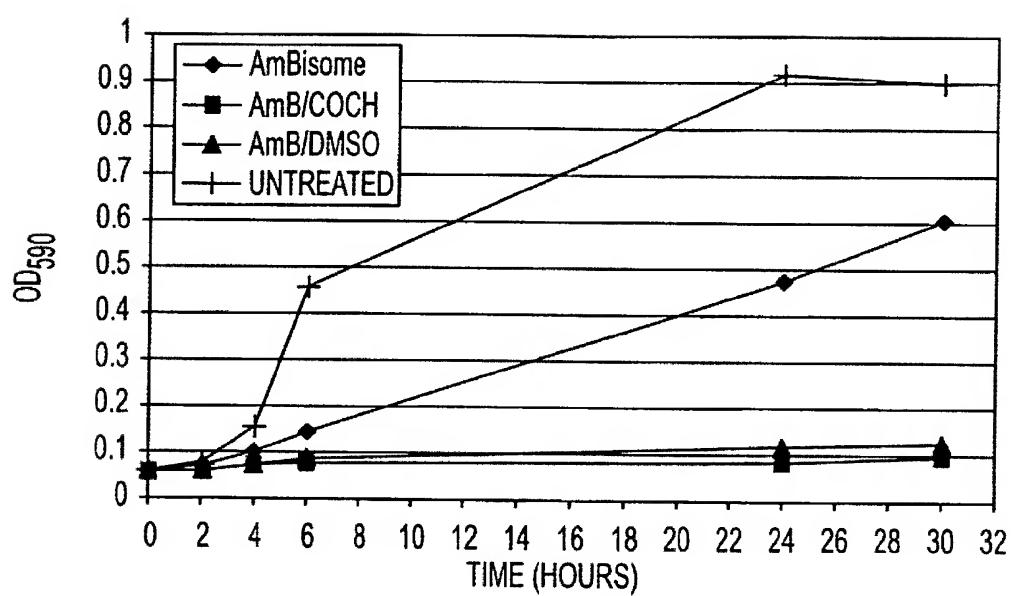


FIG. 6

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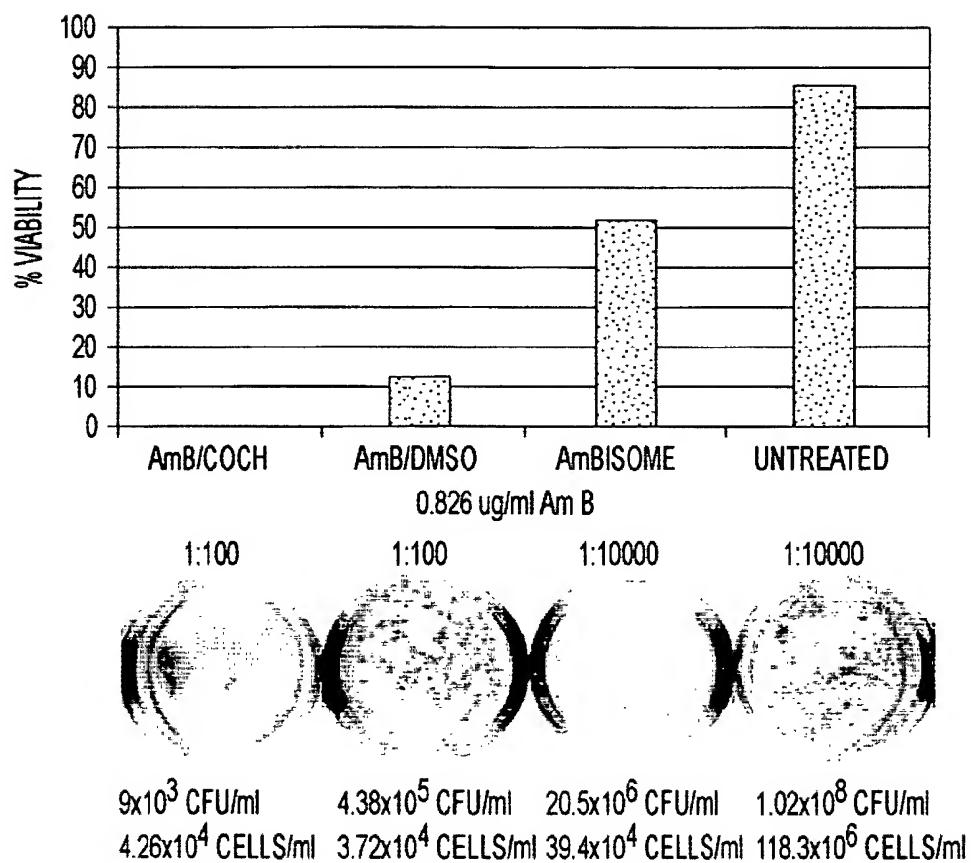


FIG. 7

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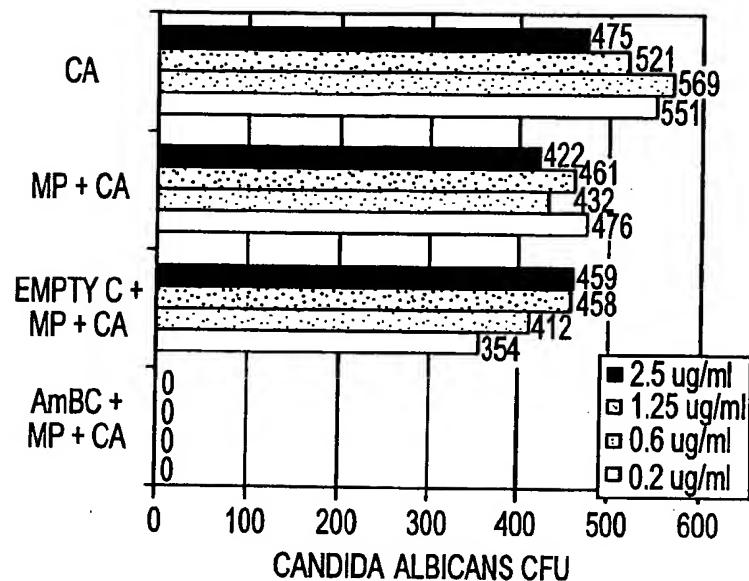


FIG. 8A

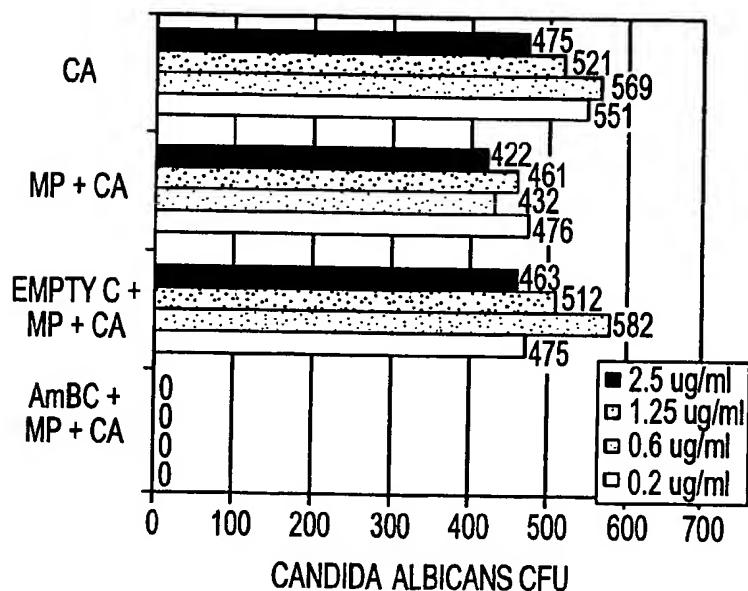


FIG. 8B

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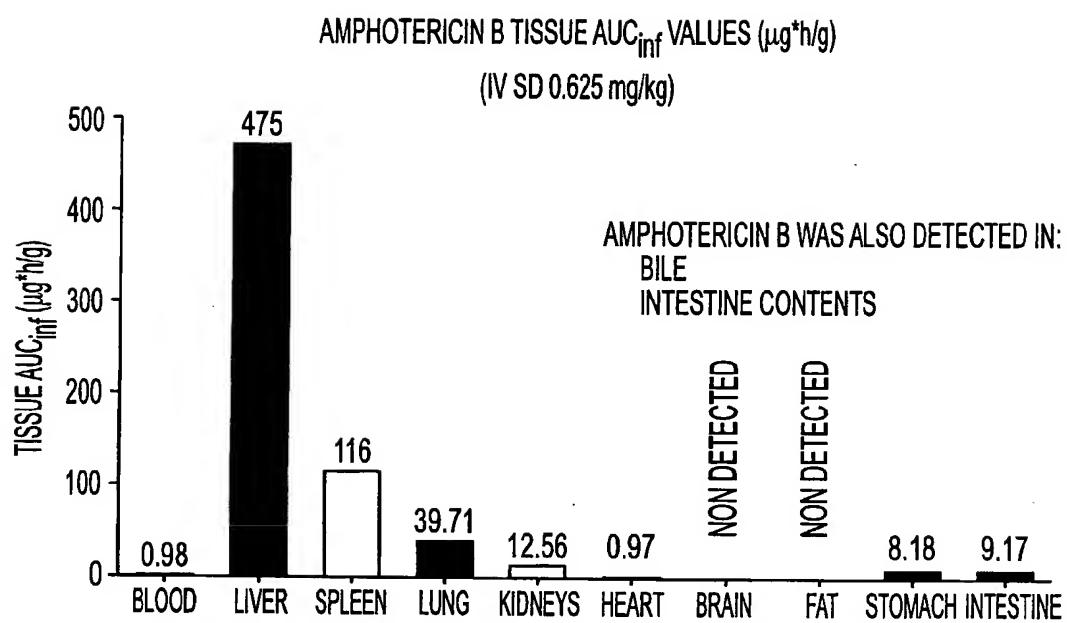


FIG. 9

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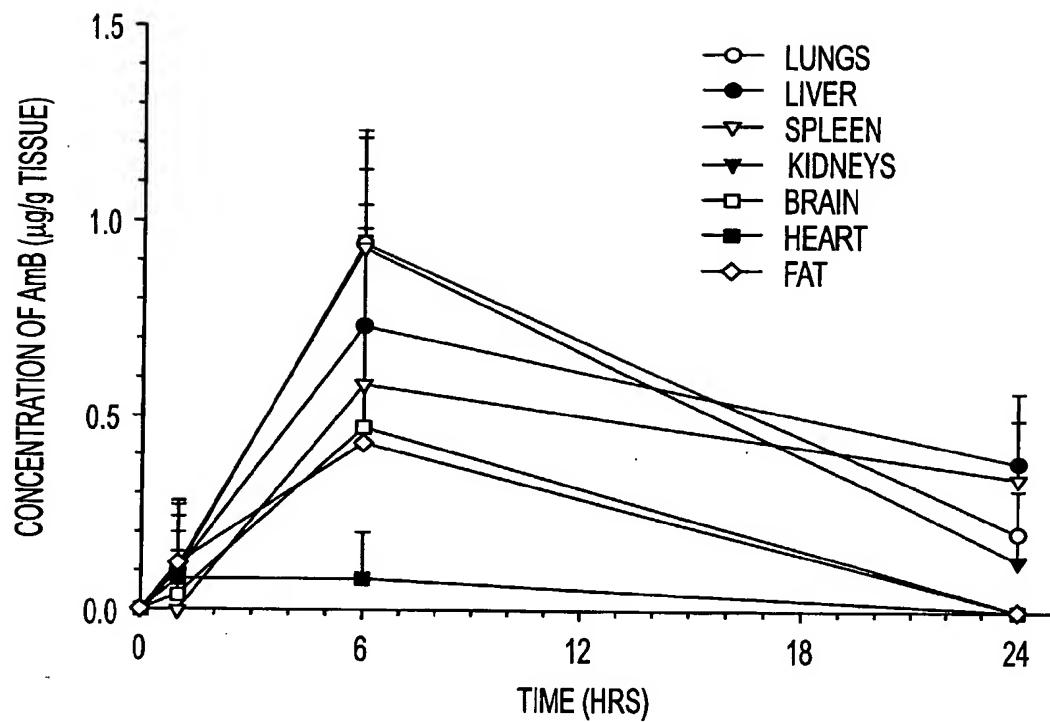


FIG.10

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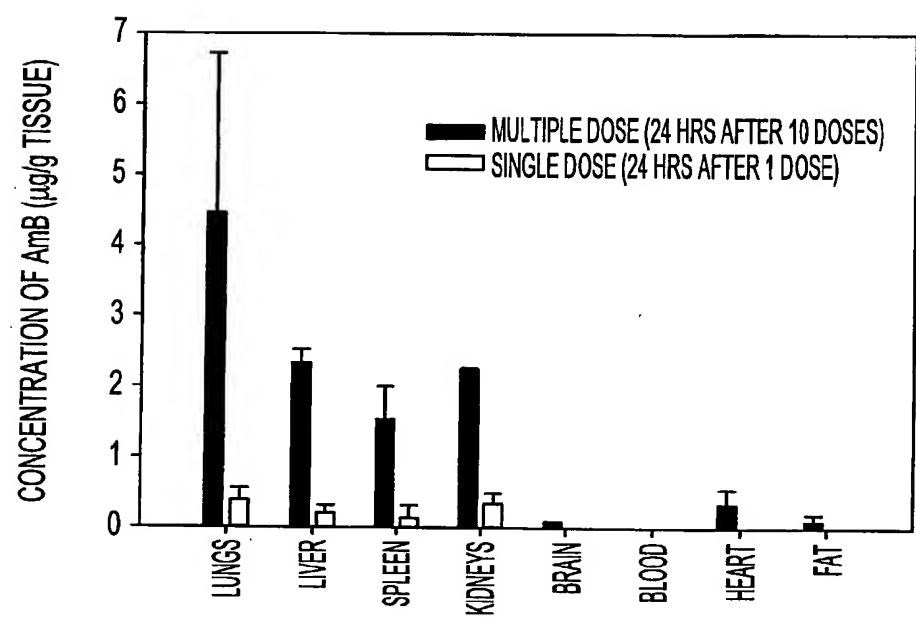


FIG. 11

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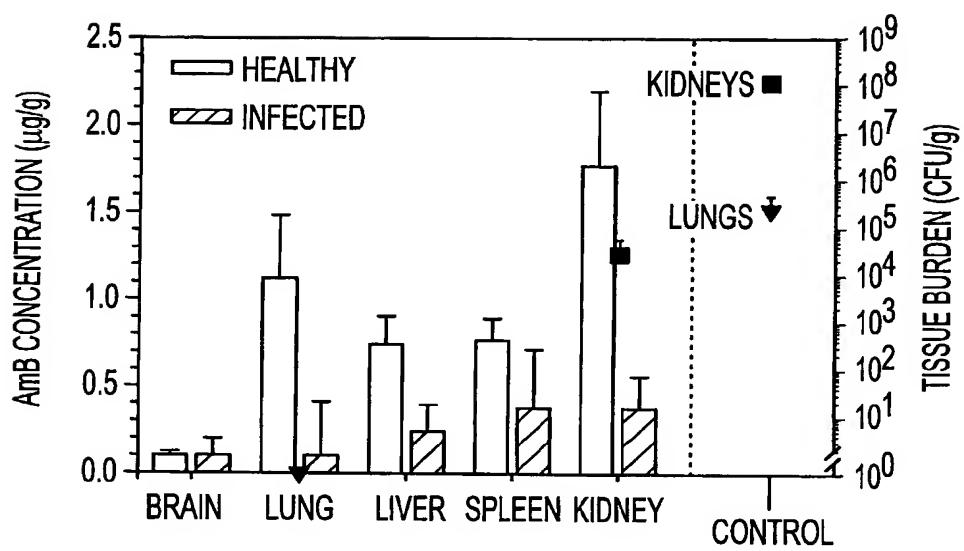


FIG. 12